CANADIAN AQUACULTURE R&D REVIEW 2015

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Cover Photo (Front): Juvenile California Sea Cucumber, *Parastichopus californicus*, perched on an oyster clump amid a forest of oyster culture strings (Photo courtesy of Dan Curtis – DFO)

Photo Inside Cover (Front): New Brunswick aquaculture site (Photo: DFO)

Photo Cover (Back): *Shutterstock*

Photo Inside Cover (Back): Rainbow Trout hatchlings, New Dundee Ontario (Photo: DFO)

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INTRODUCTION

Welcome to the sixth edition of the biannual Canadian Aquaculture R&D Review. The review is an ongoing compendium of the aquaculture research and development projects that have been underway over the past two years from all across Canada, whether they are from academia, government labs, or other research organisations. The review contains over 200 project descriptions detailing an impressive array of topics, disciplines, species and geography. Projects include marine and freshwater species, and a range of topics from finfish and shellfish health, production, husbandry technology, nutrition, integrated multi-trophic aquaculture and environmental interactions to name a few. This is the third issue of the review that has been produced by Fisheries and Oceans Canada (DFO) in partnership with the Aquaculture Association of Canada (AAC). This partnership is highly relevant, and mutually beneficial to our respective roles in the area of knowledge mobilisation at both the AAC and DFO. This collaboration has allowed us to produce this 2015 edition as an AAC Special Publication. *Electronic versions of this document are available on both the DFO and AAC websites.*

Aquaculture continues to be an important and growing sector of the seafood industry in Canada as well as globally. As aquaculture continues to grow, the role of science in supporting the sustainable and responsible development of this sector is more crucial than ever. This is coupled with the growing need for healthy and nutritious seafood products and ensuring that it occurs in an environmentally responsible manner. The AAC wants to showcase advances in aquaculture research in Canada and provide this information to its members for an expanded dialogue on present and future challenges and opportunities for the industry. This publication falls within the AAC's mandate of disseminating knowledge and further education and we hope it will be of interest to a wide audience. Likewise, Fisheries and Oceans Canada has a mandate to enable the sustainable development of Canada's aquatic resources, including aquaculture, and to provide access to information on its scientific activities underway within the department and elsewhere in Canada. Publication of ongoing aquaculture research in the Canadian Aquaculture R&D Review contributes towards achieving our shared mandates and to reach out to the science community, interested stakeholders, and the public.

We would like to take the opportunity to recognize and thank several people who contributed significantly to the production of this Review. Dan McPhee (DFO) undertook the overall coordination of this project and was instrumental in seeing this project through to completion from beginning to end. Johannie Duhaime, Tara Donaghy, Alex Tuen, Patricia Hunter, Emily Nelson, Bernadette Charpentier, and Ingrid Burgetz were also actively involved in various aspects of this project. Finally, Roger Wysocki provided oversight for all coordination of the project. We would also like to thank the AAC office staff for their support.

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FINFISH: FRESHWATER

- EFFECT OF STRESS IN SEXUALLY MATURING FEMALE BROOK TROUT (*SALVELINUS FONTINALIS*) ON EMBRYONIC DEVELOPMENT AND GENE EXPRESSION RELATED TO GROWTH IN THE EARLY DEVELOPMENT STAGES
- OPTIMIZATION OF CULTURED WALLEYE (*SANDER VITREUS*) EGG QUALITY
- REARING DEEPWATER CISCO (*COREGONUS HOYI*) IN CAPTIVITY FROM HATCH FOR RE-INDRODUCTION TO LAKE ONTARIO
- PHYSIOLOGICAL RESPONSES OF TWO CANADIAN STRAINS OF ARCTIC CHARR AT DIFFERENT LIFE STAGES TO DIETS FORMULATED WITH PLANT PROTEIN INGREDIENTS
- GENETIC SELECTION PROGRAM TO ACHIEVE IMPROVED PERFORMANCE OF BROOK TROUT STOCK FOR AQUACULTURE IN QUEBEC
- DEVELOPMENT OF GENOMIC RESOURCES FOR ATLANTIC STURGEON USING NEXT GENERATION SEQUENCING
- ASSESSING THE BIOAVAILABILITY OF SYNTHETIC METHIONINE AND LYSINE FROM DIFFERENT SOURCES IN RAINBOW TROUT (*ONCORHYNCHUS MYKISS*)
- DEVELOPMENT OF TECHNIQUES TO PROMOTE THE SURVIVAL AND GROWTH OF WALLEYE (*SANDER VITREUS*) LARVAE IN INTENSIVE CULTURE
- STUDY OF THE DIGESTIBILITY OF FLY LARVAE PRODUCT-BASED DIETS IN RAINBOW TROUT
- THE TRANSCRIPTOME AS A TOOL FOR UNDERSTANDING AND EARLY DETECTION OF VERTEBRAL MALFORMATIONS LINKED TO PHOSPHORUS DEFICIENCY IN RAINBOW TROUT
- DEVELOPMENT OF PREDICTIVE MODELING TOOLS TO ASSIST WITH FRESHWATER AQUACULTURE SITE LICENSING DECISIONS
- TOWARD EARLY DETECTION OF VERTEBRAL ANOMALIES LINKED TO PHOSPHORUS DEFICIENCY IN FARMED RAINBOW TROUT THROUGH MORPHOMETRIC MEASUREMENTS TAKEN FROM X-RAYS
- TOWARD BETTER CHARACTERIZATION OF WASTE (NITROGEN, PHOSPHORUS, SOLIDS) GENERATED BY TROUT FED WITH COMMERCIAL FEED CURRENTLY USED IN CANADA
- META-ANALYSIS OF FRESHWATER AQUACULTURE PROVINCIAL WATER QUALITY MONITORING DATA
- EFFECTS OF ENZYMES TREATED RED YEAST ON GROWTH, ASTAXANTHIN DIGESTIBILITY, AND PIGMENTATION OF RAINBOW TROUT
- REDUCING THE PROBLEM OF EARLY SEXUAL MATURATION IN ARCTIC CHARR (*SALVELINUS ALPINUS*)
- ASSESSING ECOLOGICAL INTERACTIONS BETWEEN AQUACULTURE AND WILD STRAINS OF RAINBOW TROUT
- EVALUATION OF GROWTH PERFORMANCE AND PRODUCT QUALITY OF ACRTIC CHARR (FRASER STRAIN - SIXTH GENERATION) REARED IN A COMMERCIAL OPERATION
- EVALUATION OF RATION REDUCTIONS ON THE GROWTH, FEED CONVERSION, AND SOMATIC INDICES OF RAINBOW TROUT
- AQUASTATS: ONTARIO AQUACULTURE STATISTICS PROGRAM

EFFECT OF STRESS IN SEXUALLY MATURING FEMALE BROOK TROUT (*SALVELINUS FONTINALIS*) ON EMBRYONIC DEVELOPMENT AND GENE EXPRESSION RELATED TO GROWTH IN THE EARLY DEVELOPMENT STAGES

Laurence Deneault-Tremblay extracting Brook Trout eggs. Photo: Laurence Deneault-Tremblay

This project will improve the understanding of the possible molecular impacts that parental stress may have on the fitness of Brook Trout embryos, a cultured species of importance for stocking in Quebec. This research is related to the improvement of production and culture methods, especially with regard to the health of the animals used in aquaculture.

In teleosts, maternal factors such as hormones can enter the oocytes during gonad maturation. In some species, major cortisol concentrations can be transferred into the oocytes when females are subjected to chronic stress during gonadal development. This can have harmful effects on juvenile development. The objectives of this project are to quantify the impact of prenatal maternal stress on: (1) yolk sac volume, development speed, mortality, frequency of malformations, and growth during the early development stages for Brook Trout; and (2) the relative gene expression of growth hormones and their receptors (GH, GHR, IGF 1 and IGF 1r, IGF-2) in fry.

Females were subjected to various chronic stresses during oogenesis (weekly manual stress, feed containing cortisol) and unstressed female eggs were immersed in a cortisol solution for three hours before fertilization. Various phenotypic traits were measured in the offspring of these females throughout embryonic development. Real-time quantitative PCR will be conducted on sampled fry to measure targeted gene expression.

SEP. 2013–AUG. 2015

FUNDED BY: Fonds de recherche du Québec – Nature et Technologies (FRQNT) – Team grants program **CO-FUNDED BY:** Ressources Aquatiques Québec (RAQ)

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OPTIMIZATION OF CULTURED WALLEYE (*SANDER VITREUS*) EGG QUALITY

The goal of this project is to define the nutritional requirements of walleye and to optimize the culture of this species of commercial interest (food, sport fishing) in Canada.

In order to ensure the production of commercial fry and continue the domestication process for Walleye (*Sander vitreus*), we are optimizing the initial embryonic and larval development phases in eggs produced in captivity to alleviate the need to use wild broodstock. Two major factors were targeted: (1) the use of captive broodstock to determine the "window of opportunity" for extracting eggs while avoiding the over-maturation process and excessive handling of females; and (2) manufacturing feed that meets the Walleye's nutritional requirements as well as testing its effectiveness on egg quality.

In this project, we verified the impact of broodstock age on egg quality and deduced that younger broodstock produced superior eggs. We also determined the ideal broodstock spawning time that yields the best egg quality and embryonic survival. Lastly, we defined the approximate nutritional requirements for the broodstock in terms of fatty acids, amino acids, and vitamin A.

Extraction of amino acids from Walleye eggs. Photo: Jeanette Wells

SEP. 2011–APR. 2013

FUNDED BY: Société de Recherche et de Développement en Aquaculture Continentale Inc. (SORDAC), Ressources Aquatiques Québec (RAQ) **CO-FUNDED BY:** Fonds de Recherche Nature et Technologies (BMP Innovation scholarship)

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REARING DEEPWATER CISCO (*COREGONUS HOYI*) IN CAPTIVITY FROM HATCH FOR RE-INTRODUCTION TO LAKE ONTARIO

It is believed that re-introducing Deepwater Ciscoes (*Coregonus hoyi*) will fill an important ecological niche that is currently vacant in Lake Ontario and will be a major step towards restoring the historical lake biodiversity. Re-establishment of ciscoes may also help generate healthy and stable fish populations throughout the food chain, capable of enduring sustainable exploitation for economic benefit in the future.

Until the mid-1950s, Lake Ontario was home to a diverse assemblage of ciscoes, acting as an important food source for top predators. However, biodiversity of the lake has been greatly reduced due to overfishing, shoreline development causing habitat change, and invasive species. *C. hoyi*, ("bloater") was the dominant species of cisco. The current state of the ecosystem is ideal for their successful re-introduction as factors detrimental to ecosystem health have recently been managed by government agencies, favouring increased survival of young ciscoes.

The development of culture techniques and documentation of biological information are key factors in the success of the current project at White Lake Fish Culture Station in Sharbot Lake, Ontario, operated by the Ontario Ministry of Natural Resources (OMNR). The main issue is finding a feed that is both highly acceptable to *C. hoyi* and nutritionally adequate. These are thought to be the two most critical factors affecting survival of fry. As such, the current project explores the possible benefits of co-feeding a dry diet with *Artemia nauplii* to encourage a feeding response.

To accomplish the long-term goal of a self-sustaining population in 25 years, the program requires egg collection from Lake Michigan, culture, and stocking of 500,000 juveniles every year starting in 2015.

FEB. 2012–NOV. 2015

FUNDED BY: Ontario Ministry of Natural Resources (OMNR)
CO-FUNDED BY: USFWS – Fish and Wildlife Restoration Act; Great Lakes Restoration Initiative

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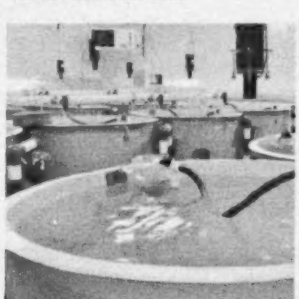
Cisco (bloater) fry, approximately three weeks after hatch. Photo: White Lake Fish Culture Station (OMNR)



Conical rearing units with individual hatching jars and vibratory feeders hanging above. Photo: White Lake Fish Culture Station (OMNR)

PHYSIOLOGICAL RESPONSES OF TWO CANADIAN STRAINS OF ARCTIC CHARR AT DIFFERENT LIFE STAGES TO DIETS FORMULATED WITH PLANT PROTEIN INGREDIENTS

Through replacing marine-sourced with terrestrial-sourced plant protein ingredients, this research in diet formulation will provide the first insights into the comparative effects of dietary plant protein inclusion in Canadian Arctic Charr. These insights may result in the reduced financial impact of Arctic Charr-targeted feed production, therefore increasing the viability of this species for aquaculture in Canada.

The National Aquaculture Strategic Action Plan Initiative (NASAPI) of the Canadian Council of Fisheries and Aquaculture Ministers (CCFAM) has targeted Arctic Charr as an alternative species holding great potential for Canadian aquaculture. The costs of feed for this species can be as high as 60% of total production depending on growth stage of the fish. As such, methods to reduce the feed budget of this species while maintaining strong growth is of primary concern. The addition of plant protein ingredients to formulated feeds has the potential to replace high cost and low availability marine-sourced ingredients such as fishmeal, while providing the fish with the amino acids required for maximum growth. However, certain plant ingredients contain anti-nutritional factors that have the potential to interact with the fish's digestive tract and alter the uptake of key nutrients. In related salmonid species, anti-nutritional factors present in soybean meal have been seen to cause intestinal inflammation, reducing protein and lipid uptake, and hindering growth. Therefore, the objectives of this project are to compare the growth, nutrient uptake, and intestinal response in two Canadian strains of Arctic Charr at the starter and grower life stages, fed diets formulated with increasing levels of both soybean and sunflower meal ingredients.

Hand-feeding tanks of juvenile Arctic Charr (*Salvelinus alpinus*). Photo: Amanda Smith (U Guelph)

MAY 2013–JUN. 2014

FUNDED BY: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund (ACOA-AIF)
CO-FUNDED BY: Manitoba Association of Agricultural Societies Inc.; Agri-Food Research & Development Initiative (ARDI)

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Icelandic Arctic Charr (*this species was not used in this particular research project*). Photo: Jim Reist (DFO)

GENETIC SELECTION PROGRAM TO ACHIEVE IMPROVED PERFORMANCE OF BROOK TROUT STOCK FOR AQUACULTURE IN QUEBEC

This research has assisted a number of Quebec aquaculture operations in gaining access to certified disease-free eggs exhibiting superior fish performance, thereby improving the profitability of their businesses.

The Brook Trout (*Salvelinus fontinalis*) is the most widely farmed species in freshwater aquaculture in Quebec. A group of farmers in Quebec, working with Centre de Transfert et de Sélection des Salmonidés (CTSS) Inc., recently launched a genetic selection program with two objectives: (1) to improve growth; and (2) to eliminate precocious sexual maturity. Two different fish strains are being used for this purpose, one of them, a decades-old domestic strain and the other the Rupert strain. The domestication process is ongoing for the Rupert strain, but early results have been encouraging in that the percentage of precocious sexual maturity at age 1+ has dropped from 36.8% to 29% without affecting growth. For the domestic strain, an 11.5% gain in growth has been recorded since the start of the program, while the percentage of precocious sexual maturity at age 0+ has decreased from 34.3% to 8.9%. Throughout the selection process, the CTSS has also ensured that all production fish are certified disease-free. The genetic enhancement process based on use of markers is ongoing.

JUL. 2011–JUL. 2014

FUNDED BY: Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ) **CO-FUNDED BY:** Société de développement de l'industrie maricole Inc. (SODIM); Société de recherche et de développement en aquaculture continentale Inc. (SORDAC); Ministère du Développement économique, de l'Innovation et de l'Exportation (MDEIE); Ministère des Affaires municipales, des Régions et de l'Occupation du territoire (MAMROT); Ressources Aquatiques Québec (RAQ)

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DEVELOPMENT OF GENOMIC RESOURCES FOR ATLANTIC STURGEON USING NEXT-GENERATION SEQUENCING

This project will significantly increase the genomic resources available for Atlantic Sturgeon. Sturgeons are a high value, caviar producing species and its aquaculture has grown exponentially in the last ten years. Market demand and growth can have negative impacts on production such as requirements for higher throughput and densities in culture. These pressures can cause stress and lead to greater susceptibility to pathogens. Clearly, a more comprehensive knowledge of sturgeon biology and genetics is needed to maximize culture and to fulfill the market demand for sturgeon products, including caviar. Unfortunately, genomic information on sturgeon is scarce. Producing these resources may help to identify elite broodstock, optimize culture conditions, and identify biomarkers for health monitoring.

In collaboration with UPEI, the Center for Aquaculture Technologies Canada (CATC) used an RNA-seq approach to identify Atlantic Sturgeon genes responsive to lipopolysaccharide (LPS) stimulation. Due to the duplicated nature of the sturgeon genome, an assembly pipeline was developed using multiple transcriptome assemblers. The transcriptome assembly generated had ~70% read re-mapping. Analysis of differentially expressed transcripts identified sturgeon LPS-responsive genes such as interleukin-8, IRF7 and inhibitory Kappa B Alpha. Additional studies will further improve the Atlantic Sturgeon reference transcriptome and identify single nucleotide polymorphisms.

AUG. 2014–JAN. 2015

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ASSESSING THE BIOAVAILABILITY OF SYNTHETIC METHIONINE AND LYSINE FROM DIFFERENT SOURCES IN RAINBOW TROUT (*ONCORHYNCHUS MYKISS*)

Both L-lysine HCL and L-lysine sulphate are able to meet lysine requirements of Rainbow Trout with equal efficiency when supplemented on an equimolar basis. Additionally, the lower bioavailability of MHA-Ca, which was found in this study, suggests feed formulators/manufacturers may wish to implement a wider safety margin when including MHA-Ca in diets in order to meet the methionine requirement of an animal.

Supplementing synthetic methionine (Met) and/or lysine (Lys) to diets of terrestrial farm animals to meet their nutritional requirements for Met or Lys is a common practice. Different forms of supplemental Met and Lys are produced and commercialized by various manufacturers. Limited information exists on the bioavailability of these different forms of Met and Lys to fish species.

Using a 12-week growth trial, relative bioavailability of L-methionine and a hydroxy methionine analogue (MHA-Ca) were compared to the commercially prevalent DL-methionine in Rainbow Trout. A separate 12-week trial investigated relative bioavailability between L-lysine HCL and L-lysine sulphate. Basal diets were formulated to be deficient in Met or Lys and were supplemented with increasing equimolar levels of Met or Lys from three sources of Met or two sources of Lys. Using a linear slope-ratio assay, bioavailability of L-methionine and DL-methionine were determined to be similar ($p>0.10$). Differences in bioavailability between DL-methionine and MHA-Ca were observed ($p<0.05$), with MHA-Ca being 69, 60, and 73% as bioavailable as DL-methionine based upon weight gain, growth rate (thermal-unit growth coefficient), and retained nitrogen response parameters, respectively. L-lysine HCL and L-lysine sulphate were effective sources of lysine with no significant differences in bioavailability ($p>0.10$).

MAY 2012–AUG. 2014

FUNDED BY: Evonik Industries AG, Hanau, Germany **CO-FUNDED BY:** Ontario Ministry of Agriculture Food and Rural Affairs (OMAFRA)

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DEVELOPMENT OF TECHNIQUES TO PROMOTE THE SURVIVAL AND GROWTH OF WALLEYE (*SANDER VITREUS*) LARVAE IN INTENSIVE CULTURE

Walleye (*Sander vitreus*) larva, 23.2 mm in length on day 24 post-hatching. Photo: Benjamin Laramée (U Laval)

The objective of this project is to promote Walleye production in Canada by reducing the financial risks associated with high mortality in the larval stage and establishing farming parameters to support optimal growth.

The Walleye (*Sander vitreus*) is a species with high commercial and recreational value in the Northern United States and Canada. Culture of this species has strong economic potential but has not been widely adopted as intensive production has yet to prove successful. Problems involving cannibalism, Non-inflation of the swim bladder, and feed ingestion have been leading to fish kills within the first few days after egg hatching. This project consequently aims to lay the groundwork for making Walleye production cost-effective by testing culture techniques currently in use elsewhere around the world and to develop new processes for promoting survival and growth at the larval stage. Various dietary treatments incorporating the use of live food and plant and/or animal protein-based feed will be tested. Additional parameters will also be evaluated, such as turbidity agents, the photoperiod, light levels, and the use of water jets and surface air. The project will ultimately lead to an economically viable plan for intensive Walleye production in keeping with demand among the table and stocking markets.

MAY 2014–DEC. 2015

FUNDED BY: Ministère de l'agriculture, des pêcheries et de l'alimentation du Québec (MAPAQ) – INNOVAMER

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STUDY OF THE DIGESTIBILITY OF FLY LARVAE PRODUCT-BASED DIETS IN RAINBOW TROUT

The objective of this project is to provide a rational basis for the formulation of new types of salmonid feed and, in so doing, demonstrate their potential for the Canadian aquaculture industry.

Incorporating fly meal into aquaculture feed formulations would help to reduce costs associated with the supply of fishery products as well as the industry's ecological footprint through the recovery of other industries' waste organic matter. However, achieving these goals depends on the capacity of meal producers to supply a consistently high-quality product that meets the needs of fish species. The choices of species, larvae production processes (substrate, environment, etc.) and product processing methods are factors potentially affecting product composition and nutritional quality. Our project aims to conduct assessments of the composition of larvae products (brown and white meals) from the Housefly (*Musca domestica*) and Black Soldier Fly (*Hermetia illucens*) grown on various substrates and then proceed with preliminary dietary testing in the Rainbow Trout to gauge nutritional quality. The composition and digestibility of foods containing 30% fly meal will be determined through analysis of total content (energy, dry matter, ash, fat, and protein) and establishment of mineral, amino acid, and fatty acid profiles.

SEP. 2014–AUG. 2015

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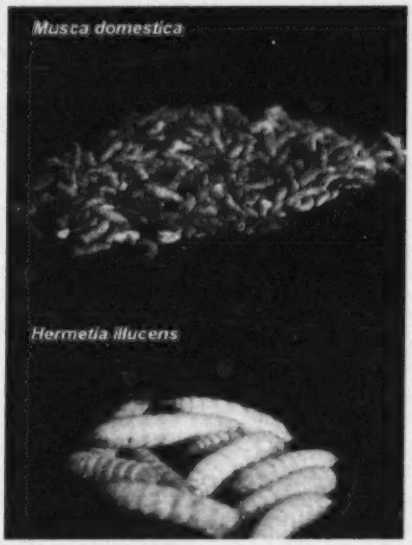

Housefly (*Musca domestica*) and Black Soldier Fly (*Hermetia illucens*) larvae. Photo: Marie-Hélène Deschamps, Émilie Proulx (U Laval)

THE TRANSCRIPTOME AS A TOOL FOR UNDERSTANDING AND EARLY DETECTION OF VERTEBRAL MALFORMATIONS LINKED TO PHOSPHORUS DEFICIENCY IN RAINBOW TROUT

Our goal is to understand the mechanisms triggering the occurrence of skeletal anomalies in farmed Rainbow Trout relating to dietary phosphorus intake. Our ultimate objective is to improve the formulation of low-phosphorus feed and support the selection of superior-performing, less polluting strains.

The occurrence of bone malformations in farmed fish poses a major financial challenge for farms in addition to raising ethical questions relating to animal well-being. Our studies have shown that a phosphorus (P) deficiency had significant impact on the occurrence of these malformations. However, previous studies have highlighted the difficulty of establishing an animal's specific needs with a view to identifying optimal P concentrations in feed. Using a leading-edge transcriptomic approach (RNA sequencing), it is now possible to detect changes in overall gene expression at specific moments relating to abnormal animal development. As such, our studies have shown that in fish with a P deficiency that develop malformations, a number of signalling pathways identified in humans are also affected in the Rainbow Trout. These events appear to lead to abnormal bone mineralization and decreased robustness, potentially making the bone more susceptible to malformations. Our studies have also shown that some malformations could be reversible up to a certain point. These advanced detection tools could also be used to prevent and/or limit the occurrence of adverse structural changes in animals during the rapid growth phase.

SEP. 2010–AUG. 2014

FUNDED BY: Ministère du Développement économique, de l'Innovation et de l'Exportation – Programme de soutien à des initiatives internationales de recherche et d'innovation (PSIIRI) **CO-FUNDED BY:** DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP); Programme de recherche et de développement en aquaculture continentale (SORDAC); Réseau Aquaculture Québec – Programme de bourse FONCER; Université Laval – Programme de bourse du Bureau International

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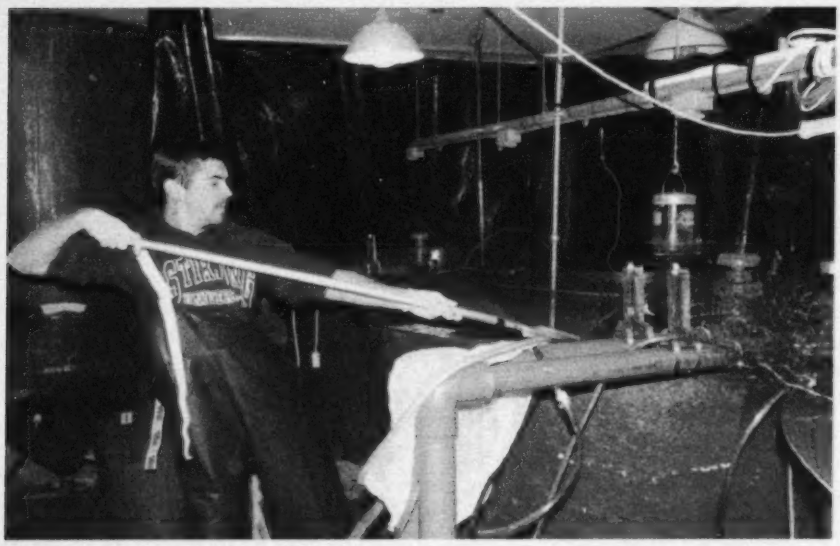

Cleaning the tanks. Photo: Emilie Proulx (U Laval)

DEVELOPMENT OF PREDICTIVE MODELING TOOLS TO ASSIST WITH FRESHWATER AQUACULTURE SITE LICENSING DECISIONS

Governmental agencies charged with the responsibility of licensing and regulation of the aquaculture industry are in need of objective tools to assist in their decision-making processes. The development of such tools would similarly be of benefit to the industry, as currently the primary factor limiting the expansion of the freshwater industry is access to new sites. The lack of tools to estimate ecological consequences of new sites has resulted in a very precautionary atmosphere, a complex and expensive application process and, ultimately, limited development of the industry.

The primary environmental concerns with cage aquaculture are related to benthic impacts and exceedance of the assimilative capacity of an ecosystem for nutrient inputs. Cage aquaculture has the potential to have far-ranging impacts on the lake ecosystem. Increased nutrient inputs can affect overall ecosystem productivity and excessive nutrient inputs can lead to eutrophication, which may include such undesirable consequences as development of nuisance algal blooms, oxygen deficient, and loss of biodiversity. The deposition of solid wastes under farms contributes to increased sediment oxygen demand as well as the potential to significantly alter the quality of benthic habitat and the composition of benthic communities beneath and surrounding farms.

APR. 2008–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP)
CO-FUNDED BY: Wild West Steelhead

PROJECT LEAD: Cheryl Podemski (DFO)

COLLABORATORS: Wild West Steelhead

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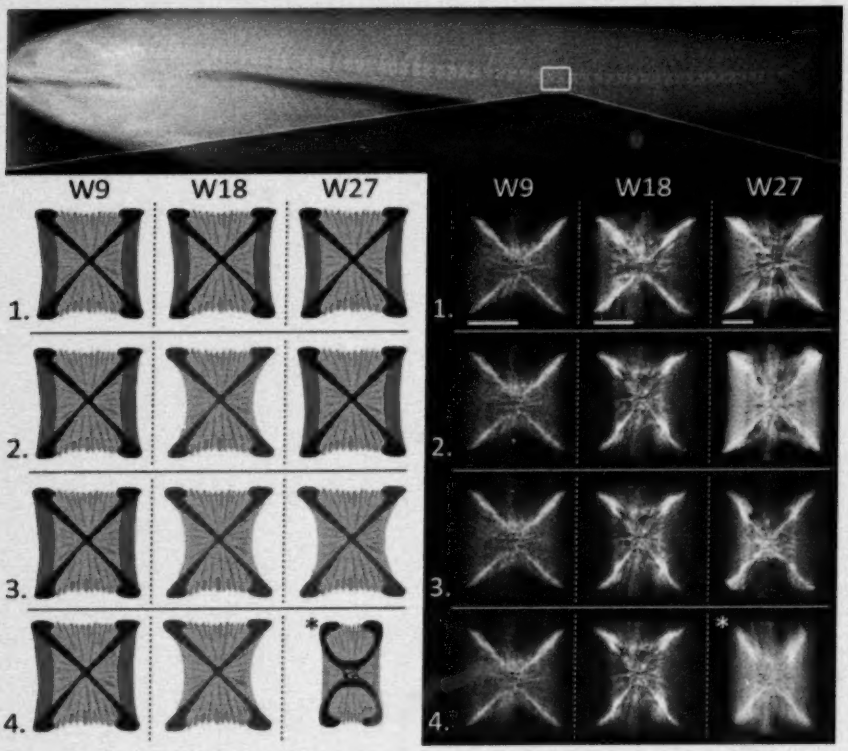
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

TOWARD EARLY DETECTION OF VERTEBRAL ANOMALIES LINKED TO PHOSPHORUS DEFICIENCY IN FARMED RAINBOW TROUT THROUGH MORPHOMETRIC MEASUREMENTS TAKEN FROM X-RAYS



Schematic depiction and x-rays of the four vertebral development scenarios observed in the study. Scenarios are depicted in three stages representing the beginning, middle, and end, respectively, of the experimental phase (weeks 9, 18, 27). The vertebrae shown display two types of malformations: biconcave and compressed. Image: from Poirier Stewart *et al.* J. Appl. Ichthyol. 30 (2014), p.796–803

Our goal is to understand the mechanisms triggering the occurrence of skeletal anomalies in farmed Rainbow Trout relating to dietary phosphorus intake and to be able to describe in detail the morphological changes occurring in the vertebral structure.

The development of vertebral anomalies is a recurring problem in intensive salmonid culture that generates financial losses and raises ethical concerns. Our research on vertebral malformations induced by prolonged phosphorus deficiency has enabled identification of the anomalies characteristic of phosphorus deficiency as well as the vertebral phenotypic plasticity exhibited by farmed Rainbow Trout. Under the same conditions, the caudal vertebrae of Rainbow Trout exhibited four different development scenarios: (1) development and maintenance of a normal phenotype (17% of individuals); (2) development of an abnormal phenotype followed by full recovery (24%); (3) development and maintenance of an abnormal phenotype (16%); and (4) development of an abnormal phenotype followed by phenotype deterioration (16%). Morphometric measurements taken from x-rays of the vertebrae combined with analysis of histological sections enabled detection of morphological changes otherwise imperceptible upon visual x-ray analysis. We therefore proposed a standardized method for early detection of these types of vertebral anomalies that may be used by stakeholders throughout the Canadian aquaculture industry to ensure optimal vertebral development.

SEP. 2010–AUG. 2014

FUNDED BY: Ministère du Développement économique, de l'Innovation et de l'Exportation – Programme de soutien à des initiatives internationales de recherche et d'innovation (PSIIRI) **CO-FUNDED BY:** DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP); Programme de recherche et de développement en aquaculture continentale (SORDAC); Réseau Aquaculture Québec – Programme de bourse FONCER; Université Laval – Programme de bourse du Bureau International

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COLLABORATORS: Nadia Aubin-Horth, Claude Robert, Arnaud Droit (U Laval); Dominique Bureau (U Guelph); Ann Huysseune, Eckhard Witten (Universiteit Gent); Jean-Yves Sire (U Paris 6); Chantal Cahu, Dominique Mazurais (IFREMER); Kenneth Overturf, Ron Hardy (U Idaho); Tom Hansen, Anna Wargelius, P.E. Fjelldal (Havforskningsinstituttet)

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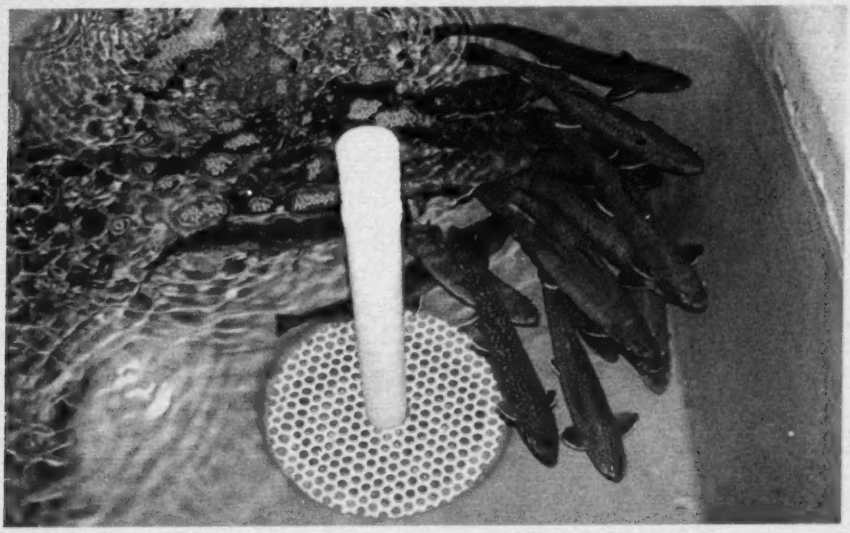
TOWARD BETTER CHARACTERIZATION OF WASTE (NITROGEN, PHOSPHORUS, SOLIDS) GENERATED BY TROUT FED WITH COMMERCIAL FEED CURRENTLY USED IN CANADA



Trout housed in a tank at University of Laval. Photo: Grant Vandenberg (U Laval)

Eutrophication of watercourses, into which waste from aquaculture operations flow, constitutes the most concerning environmental impact for the Canadian trout aquaculture industry. Significant efforts have been made in recent years to reduce the quantity of nutrients (i.e., phosphorus (P), nitrogen (N), and suspended solids) emitted by fish culture. New feeds have, therefore, been developed to limit the total quantity of P and N in waste from cultivated fish stocks. Accurate bioenergetic models have also been developed to determine fish growth, feeding standards, and retention and excretion of nitrogen and phosphorus. However, accurate coefficients must be determined to operate these models and these values vary depending on the fish stock and feed used. The goal of this study was to accurately determine the growth and apparent digestibility coefficients of the nutrients in various commercial feeds for Rainbow Trout (50 to 500 g) and Brook Trout (50 to 250 g) of different sizes in temperatures of 8 °C and 14 °C.

Proximate analysis of the 22 commercial feeds examined showed that most of the feeds had phosphorus content below the posted maximum commercial values. Differences of -30% to 20% were observed between the actual and theoretical contents. Growth and apparent digestibility coefficients were determined for each feed based on the species, life stage, and culture temperature. The results obtained relative to the characterization of waste (i.e., nitrogen, phosphorus, and solids) varied depending on the feeds and production batches. These new coefficients will be used in mathematical models to estimate the quantity of nutrients released by operations. The data obtained will help aquaculture regulators and the industry evaluate the systems required to process effluents and reduce the sector's ecological footprint.

APR. 2009–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP)
CO-FUNDED BY: Industrial Action Plan of the Interprovincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD)

PROJECT LEAD: Grant Vandenberg (U Laval)

PROJECT TEAM: Éric Boucher, Annie Dubé, Émilie Proulx (U Laval)

COLLABORATORS: Industrial Action Plan of the Interprovincial Partnership for Sustainable Freshwater Aquaculture Development (IPSFAD)

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

META-ANALYSIS OF FRESHWATER AQUACULTURE PROVINCIAL WATER QUALITY MONITORING DATA

Recent increases in production capacity in Ontario, Saskatchewan, and British Columbia have prompted regulators to consider strategies for managing freshwater finfish aquaculture, in particular, ecosystem carrying capacity which is tightly coupled with the phosphorus released in aquaculture waste. Currently in Ontario, a water quality monitoring program is imposed as a condition to aquaculture licenses to ensure that the release of phosphorus from finfish farms does not exceed regulatory thresholds. The program, however, does not address phosphorus levels near or downstream from freshwater finfish farms, or if phosphorus concentrations have increased over the decade that sampling has been conducted. One of the primary environmental concerns restricting the expansion of the freshwater finfish cage industry is the ability of the environment to assimilate waste, in particular phosphorus. Phosphorus is the nutrient that limits the biomass of primary producers; excessive amounts of phosphorus released from aquaculture cages pose a risk of eutrophication in freshwater ecosystems.

A decade of water monitoring data collected through the historic Ontario monitoring program will be analyzed to determine if there is evidence that freshwater finfish cages are contributing to elevated phosphorus concentrations and to the eutrophication in the environment. Given the link between assimilation of phosphorus and carrying capacity, the results of this project will provide further insight to the role of ecosystem carrying capacity in accommodating sustainable expansion of the industry.

AUG. 2014–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Cheryl Podemski (DFO)

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EFFECTS OF ENZYMES TREATED RED YEAST ON GROWTH, ASTAXANTHIN DIGESTIBILITY, AND PIGMENTATION OF RAINBOW TROUT

This research may offer an effective way to reduce the cost of pigmentation in the production of salmonids. The muscle colour of Rainbow Trout is an important quality attribute, which has a major impact on consumers' perception and willingness to pay. The red/pink color of the fillet is achieved by the deposition of carotenoid pigments, mainly astaxanthin, within muscle fibers. Fish are unable to synthesize astaxanthin *de novo*, hence it must be obtained through dietary sources. Pigment supplementation may represent up to 15% of the total feed costs due to the high price of synthetic astaxanthin. Astaxanthin from single cell organisms are a protein-rich alternative source of pigments for aquaculture feed. Until now, the incomplete breakage of red yeast is the main obstacle that results in low astaxanthin digestibility and poor pigmentation in fish. Previous research showed that there was a positive relationship between the degree of enzymatic cell wall disruption and astaxanthin deposition in muscle when Rainbow Trout were fed diets supplemented with red yeast. Thus, the objectives of this study are: (1) to assess effects of a glucanase-protease combination on the availability of astaxanthin from red yeast *in vitro* trial; and (2) to assess the effects of enzyme complexes on astaxanthin digestibility, growth, and muscle pigmentation of Rainbow Trout.

MAY 2014–JAN. 2015

FUNDED BY: Jefo Nutrition Inc.

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PROJECT TEAM: Xinwen Yi, Patricio Saez (U Guelph)

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REDUCING THE PROBLEM OF EARLY SEXUAL MATURATION IN ARCTIC CHARR (*SALVELINUS ALPINUS*)

Early sexual maturation among diploid Arctic Charr and other farmed salmonids remains a serious problem, reducing meat quality and revenue. Photoperiod, temperature, and food availability exert a strong influence on somatic growth and the decision to commence sexual maturation, but how they interact is unclear. Fraser River Arctic Charr is a good model for study as both sexes suffer a high rate of early sexual maturation age 2+ in culture, a trait that has limited its commercialization in Canada. Initial trials established 24 h light (LL) for several months during winter age 1+ reduced significantly the maturity rate age 2+ in a step-wise manner, the earlier LL started in autumn the fewer mature fish. Paradoxically, gonadal maturation was stimulated by the onset of LL, and was subsequently arrested by the return of the natural day length in April–May. Ongoing trials are quantifying the relative importance of the three phases of the LL photoperiod regime: LL start date, LL duration, and LL end date. The best LL regime might cut the maturity rate to 40%, but this is still too high for farmers. Substantial further reductions in maturity rate to <10% was achieved recently when we combined LL with a period of food deprivation and reducing temperature from 10°C to 5°C. Compensatory growth following the return to full ration indicates the technique is useful to growers. Moreover, knowing how to switch off maturation provides a means to explore the neuroendocrine mechanisms controlling seasonal maturation.

SEP. 2013–ONGOING

FUNDED BY: Atlantic Innovation Fund

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PROJECT TEAM: Qi Liu (Dalhousie U)

COLLABORATORS: Andre Dumas (CZRI); Tony Manning (RPC)

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Top: Marketable silvery immature fish, bottom: unmarketable highly colored mature fish. Photo: Paul MacIsaac (Dalhousie U)
Bottom: Marketable silvery charr held by Qi Liu, and unmarketable mature charr held by Minmin Wei.
Photo: Paul MacIsaac (Dalhousie U)

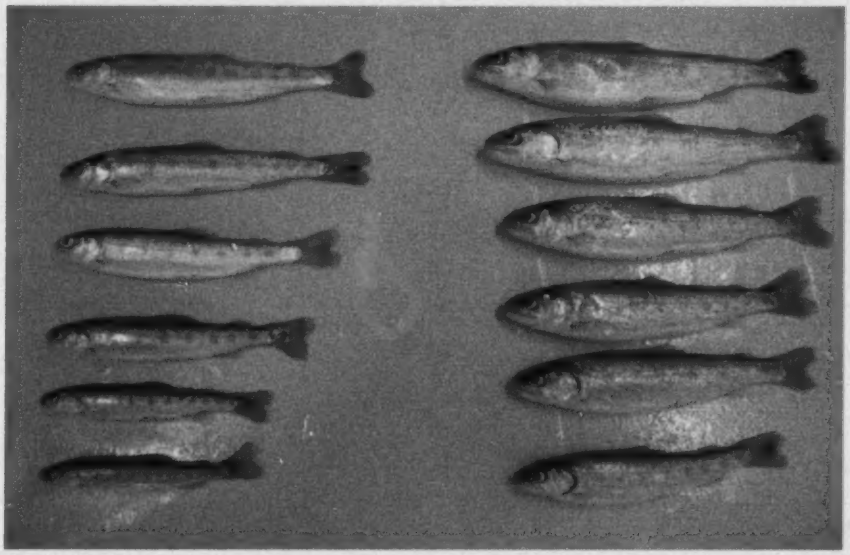
ASSESSING ECOLOGICAL INTERACTIONS BETWEEN AQUACULTURE AND WILD STRAINS OF RAINBOW TROUT

Whole-ecosystem studies are critical to understanding the potential consequences that growth-enhanced strains of fish used in commercial aquaculture may pose to wild fish communities. We conducted laboratory trials and whole-ecosystem studies to investigate the differences in growth and survival of aquaculture versus wild (or naturalized) strains of Rainbow Trout common to Lake Huron. From growth trials, we documented that the strain of Rainbow Trout used in commercial production in Lake Huron grew to double the size of wild fish. Rapid growth of aquaculture strain fish was achieved by greater feed consumption and higher feeding efficiency relative to wild fish.

Next, we stocked equal densities of these same Rainbow Trout strains into a small, boreal lake. Both trout strains occupied similar near-shore habitat, and experienced equally low survival. This we attributed to predation from loons and mergansers. The aquaculture strain segregated into a fast-growing group (~3x growth relative to the wild strain), and a slow-growing group that had a lower growth rate than wild trout. Fast-growing aquaculture trout had the greatest proportion of high energy prey (minnows) in their diet, whereas wild fish were more reliant upon insects.

Our findings demonstrate that the aquaculture strain of Rainbow Trout, which is present in Lake Huron through escape from net pens, has the potential to outcompete wild strains when they occupy similar near-shore habitats.

University of Manitoba graduate students Matt Martens (left) and Matt Guzzo (right) gillnet for aquaculture and wild strains of Rainbow Trout stocked at the Experimental Lakes Area, Ontario. Photo: Alex Wall (DFO)



A strain of Rainbow Trout used in commercial aquaculture in Lake Huron (right) has enhanced growth compared to the wild strain (left) from Lake Huron. Photo: Alex Wall (DFO)

MAY 2010–MAR. 2013

FUNDED BY: DFO - Centre for Aquatic Biotechnology Regulatory Research (DFO – CABRR)

PROJECT LEAD: Paul Blanchfield (DFO)

PROJECT TEAM: Robert Devlin, Alex Wall (DFO); Matthew Martens (U Manitoba)

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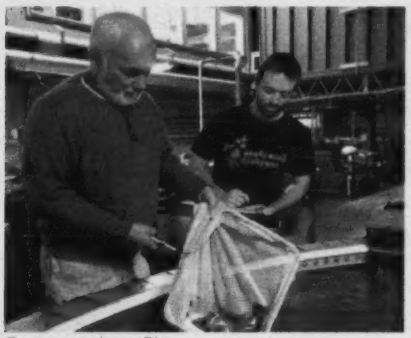
EVALUATION OF GROWTH PERFORMANCE AND PRODUCT QUALITY OF ARCTIC CHARR (FRASER STRAIN - SIXTH GENERATION) REARED IN A COMMERCIAL OPERATION



Fraser strain Arctic Charr

Arctic Charr is listed as an alternative species that holds great potential for commercial aquaculture in Canada. The objective of the project is to evaluate the performances as well as product quality of Arctic Charr (Fraser strain, 6th generation) in a local commercial fish farm. These fish will be reared under intensive conditions until they reach market size (about 1300 g). In July 2014, the mean body weight of juveniles was 7 g. From July to October 2014, the feed conversion and thermal-unit growth coefficient were 0.88 and 0.229, respectively. The average temperature was 8.6°C. The mean stocking density was 36 kg/m³. Only 0.9% mortality was observed so far. This major project is the first of its kind to be conducted on the Fraser strain at a commercial scale.

The results will serve as an indication of the performance that can be expected from this strain in a typical commercial rearing environment. These results will also be used to plan the financial aspects of commercial businesses.

JUL. 2014–DEC. 2015

FUNDED BY: Department of Agriculture, Aquaculture and Fisheries of New Brunswick **CO-FUNDED BY:** NRC – Industrial Research Assistance Program (NRC – IRAP); Pisciculture Acadienne (PA); Coastal Zones Research Institute (CZRI)

PROJECT LEAD: Claude Pelletier (CZRI)

PROJECT TEAM: Luc Desjardins (NBCC); Michel Desjardins (NBDAAF); Emmanuel Chiasson, André Vienneau, Robert Mallet (PA); André Dumas (CZRI)

COLLABORATORS: Pisciculture Acadienne (PA)

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EVALUATION OF RATION REDUCTIONS ON THE GROWTH, FEED CONVERSION, AND SOMATIC INDICES OF RAINBOW TROUT

In this study, Rainbow Trout were fed by hand to near satiation for two days followed by a reduction in the amount of feed fed for the remaining five days of the week. The reduction in food presented was based on a percentage of the total feed taken during the previous two hand feeding events. The ration reduction levels were to 88%, 81%, 74%, and 67% of satiation. A fifth ration strategy involved feeding by hand to near satiation for two days followed by one day of fasting. The feed was then reduced to 85% of satiation for the remaining four days of the week.

There were no significant differences in growth, degree of population size variation, mortalities, or visceral weight to total body weight (viscerosomatic index or dress-out loss) due to degree of ration reduction in this trial. The only differences of significance occurred with the feed conversion ratios (FCR). As the degree of ration reduction increased, the FCR's improved without impacting growth. The poorest feed conversion ratio was at the 88% ration level (FCR = 1.23). Fish fed at the 67% ration level and at the 85% + one day fasting ration level had significantly better FCR's than those fed at the 88% ration levels.

The efficiency with which fish utilize a food supply is a major factor determining the economic returns of a fish farm. While research has investigated the dietary requirements of Rainbow Trout resulting in the formulation of highly effective diets, the quantity of food eaten and the manner in which it is presented to Rainbow Trout and its effects on growth rate and feed conversion efficiencies have been less studied.

JAN. 2013–OCT. 2013

FUNDED BY: Martin Mills Inc. **CO-FUNDED BY:** Ontario Ministry of Agriculture, Food and Rural Affairs

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PROJECT TEAM: Mark Wagner (Martin Mills Inc.)

COLLABORATORS: Alma Aquaculture Research Station (U Guelph)

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Alma Aquaculture Research Station. Photo: University of Guelph

AQUASTATS: ONTARIO AQUACULTURE STATISTICS PROGRAM

In 2013, we estimate that Ontario fish farms produced 3,580 tonnes of Rainbow Trout, primarily for human consumption. Lake-based cage production of Rainbow Trout in the Georgian Bay area accounts for 89% of the total production. Our records suggest that approximately 55-60 facilities culture Arctic Charr, tilapia, Brook Trout, bass and other species, with an estimated total production of 210 tonnes in 2013.

The total farm-gate value of the 3,580 tonnes of Rainbow Trout produced is estimated to be $18 million, with an average price of $5.02/kg. The sale of Arctic Charr, tilapia, Brook Trout, bass and other fish species is estimated to be an additional $1.2 million. More than 40 facilities are involved with pond stocking, typically Rainbow Trout, Brook Trout and bass, conservatively estimated to be $1.5 million annually.

The Ontario aquaculture industry is estimated to have generated a total of 172 person-years of direct, on-farm employment (107 person-years of full-time and 65 person years of part-time employment). Indirect employment is conservatively estimated at 150 person-years. The total annual contribution that aquaculture makes to the Ontario economy is estimated to be $60 million, with additional economic value realised via the recreational and aquaria trade.

JAN. 2013–MAR. 2013

FUNDED BY: Ontario Ministry of Natural Resources **CO-FUNDED BY:** Ontario Ministry of Agriculture, Food and Rural Affairs

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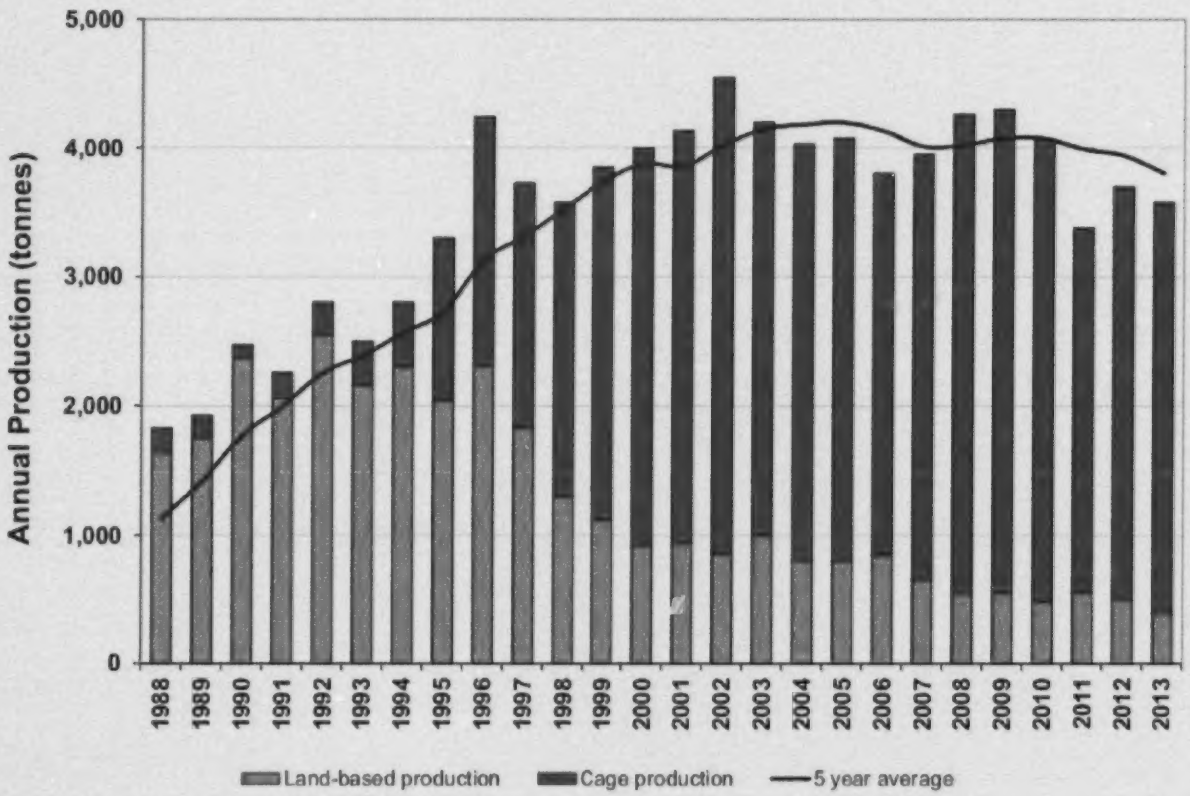
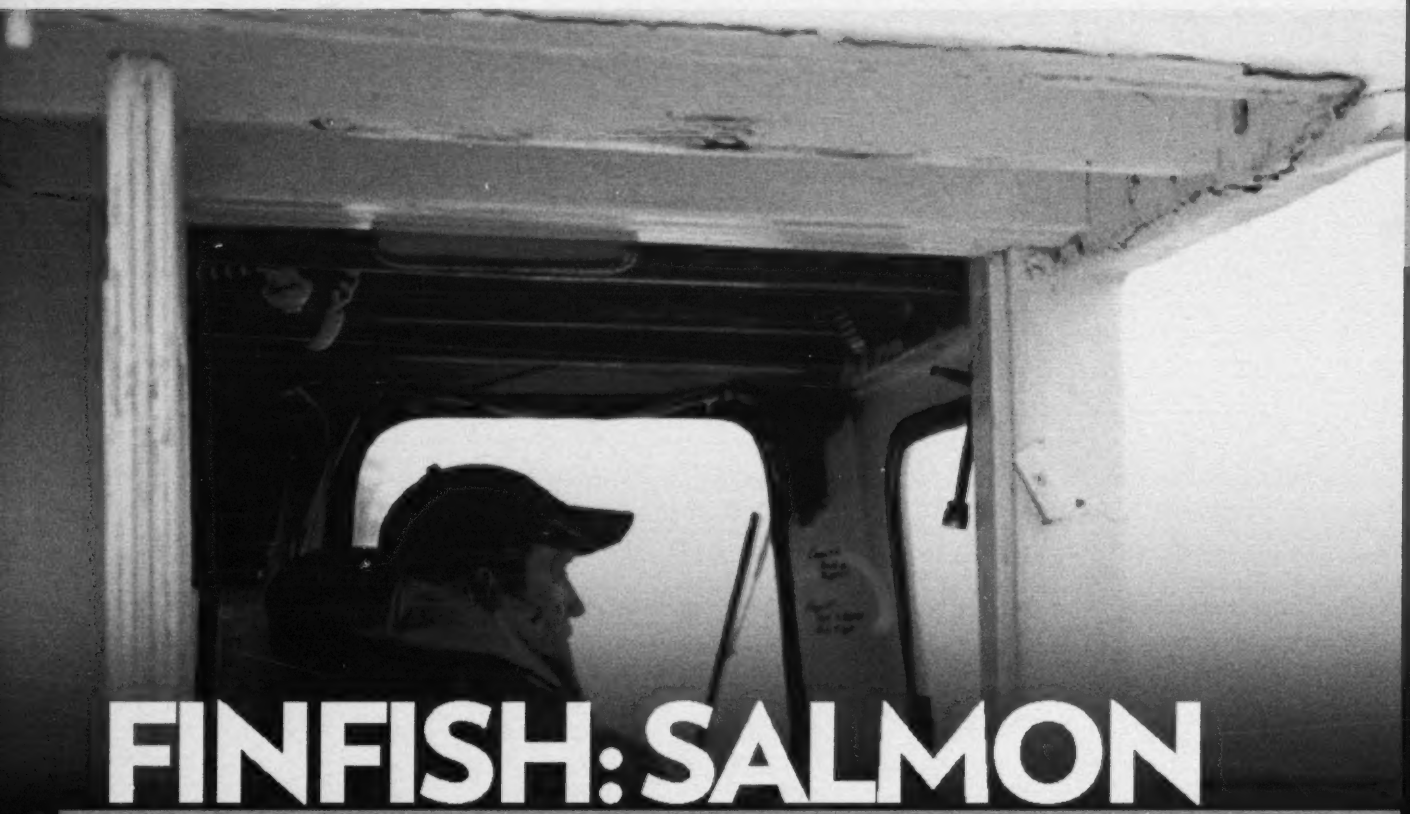


Ontario Trout Production: 1998-2013



FINFISH: SALMON

- INNOVATION THROUGH COLLABORATION: RECOVERING AN ENDANGERED POPULATION OF ATLANTIC SALMON THROUGH PARTNERSHIP WITH ATLANTIC CANADA'S AQUACULTURE INDUSTRY
- ATLANTIC SALMON SELECTION AND BROODSTOCK DEVELOPMENT PROGRAM FOR USE IN COMMERCIAL SALTWATER AQUACULTURE PRODUCTION ON THE EAST COAST OF CANADA
- EFFECTS OF FEEDING HIGH PLANT PROTEIN DIET ON GROWTH AND NUTRIENTS UTILIZATION OF GROWTH HORMONE TRANSGENIC DIPLOID AND TRIPLOID ATLANTIC SALMON (*SALMO SALAR* L.)
- THE EFFECT OF OPERCULAR DEFORMITY ON FISH WELFARE AND AEROBIC CAPACITY
- ANALYSIS OF THE INCIDENCE OF ATLANTIC SALMON DEFORMITIES IN PRODUCTION - ENVIRONMENTAL OR GENETICS?
- DETERMINATION OF THE POTENTIAL SPATIAL OVERLAP AND INTERACTION BETWEEN COMMERCIAL FISHERIES (AMERICAN LOBSTER, SNOW CRAB) AND FINFISH AQUACULTURE ACTIVITIES IN CONNAIGRE BAY, NEWFOUNDLAND
- REDUCTION OF AMMONIA AND SOLIDS FROM CHINOOK SALMON CULTURE FACILITIES
- DEVELOPMENT OF HIGH PERFORMANCE CHINOOK SALMON STOCKS FOR COMMERCIAL AQUACULTURE: GENETIC HYBRIDIZATION TO MAXIMIZE CULTURE EFFICIENCY AND MINIMIZE ENVIRONMENTAL IMPACT
- DETECTING HYBRIDIZATION AMONG WILD AND FARMED ESCAPED ATLANTIC SALMON IN SOUTHERN NEWFOUNDLAND: FIELD COLLECTIONS
- THERMAL AND pH TOLERANCE OF FARMED, WILD, AND FIRST GENERATION FARMED-WILD HYBRID SALMON
- INVESTIGATION OF FARM-ORIGIN ESCAPED ATLANTIC SALMON IN NEWFOUNDLAND
- DEVELOPMENT OF A LOW DENSITY SNP ARRAY FOR PARENTAGE ASSIGNMENT IN ATLANTIC SALMON
- DEVELOPMENT OF QUANTITATIVE HISTOLOGICAL METHODS FOR UNDERSTANDING THE BONE METABOLISM OF FISH AND PREVENTING THE OCCURRENCE OF VERTEBRAL ANOMALIES IN FARMED SALMONIDS
- REPRODUCTION TRIALS BETWEEN WILD AND FARMED SALMON
- MIGRATION TIMING AND DISTRIBUTION OF JUVENILE SALMON IN DISCOVERY ISLANDS AND JOHNSTONE STRAIT
- INDIVIDUAL AND FAMILY RESISTANCE TO BACTERIAL KIDNEY DISEASE IN SAINT JOHN RIVER STRAIN ATLANTIC SALMON
- ECOLOGICAL EFFECTS OF BLUE LED LIGHTS USED AT MARINE FINFISH AQUACULTURE SITES IN BRITISH COLUMBIA
- DEVELOPING STANDARD OPERATING PROCEDURES TO QUANTIFY SPERM DENSITY AND DILUTE OR EXTEND MILT FROM MALE SAINT JOHN RIVER STOCK ATLANTIC SALMON TO ENHANCE MANAGEMENT OF A BROODSTOCK PROGRAM
- GENETIC AND GENOMIC IMPACTS OF ESCAPED FARMED SALMON IN ATLANTIC CANADA: EVALUATING THE USE OF ARCHIVED ATLANTIC SALMON SCALES AS A SOURCE OF PRE-IMPACT DNA
- SPATIAL AND TEMPORAL DISTRIBUTION AND SURVIVAL OF FARMED ATLANTIC SALMON AFTER EXPERIMENTAL RELEASE FROM SEA CAGE LOCATIONS
- SALMON AND CHIPS: COMMERCIAL APPLICATION OF GENOMICS TO MAXIMIZE GENETIC IMPROVEMENT OF FARMED ATLANTIC SALMON ON THE EAST COAST OF CANADA
- RAPID GENOMIC SCREENING FOR ATLANTIC SALMON AQUACULTURE ESCAPEES AND HYBRIDS USING A HIGH THROUGHPUT NANOFLUIDIC DYNAMIC ARRAY
- SUSTAINABILITY OF FISH FARMING: AN ECOSYSTEM APPROACH
- BETTER FEED FOR BETTER FISH: BIOMARKER PLATFORM FOR COMMERCIAL AQUACULTURE FEED DEVELOPMENT
- CYCLICAL FEEDING STRATEGY TO REDUCE ENVIRONMENTAL IMPACT OF MARINE SALMON FARMING

INNOVATION THROUGH COLLABORATION: RECOVERING AN ENDANGERED POPULATION OF ATLANTIC SALMON THROUGH PARTNERSHIP WITH ATLANTIC CANADA'S AQUACULTURE INDUSTRY

The development of a 'conservation sea cage' rearing strategy for wild salmon has the potential to return adults to their native rivers in numbers rivalling historic highs, provided sufficient smolts can be collected. This model could then boost not only salmon demographics, but aquatic ecosystem processes which are currently limited by a lack of diadromous fish populations. This project is an important demonstration of collaborative species recovery involving government, non-government, industry, academic and First Nation partners.

Building on the success of a pilot project in 2009–2012, an innovative yet practical rearing strategy has been implemented to boost endangered inner Bay of Fundy (iBoF) Atlantic salmon populations in two native rivers. Inner Bay of Fundy salmon smolts are collected from the wild by Parks Canada and Fort Folly First Nation and are transported to specially designed 'conservation sea cages' maintained by Cooke Aquaculture, with support from the Atlantic Canada Fish Farmers Association. Prior to stocking, wild smolts undergo rigorous health testing in a closed containment, salt water rearing facility at Huntsman Marine Science Centre. Three important benefits of conservation sea cage rearing are expected: (1) post-smolts will mature in a semi-natural environment in the Bay of Fundy; (2) significant numbers of adults can be produced for release back to native rivers to spawn; and (3) by reproducing in the wild, these adults will produce progeny that are free of captive exposure and associated domestication effects. Annual iterations of this program are hoped to contribute to wild population fitness through increasing generations of wild-produced smolts.

MAR. 2014–MAR. 2019

FUNDED BY: Government of Canada, National Conservation Plan funding **CO-FUNDED BY:** All collaborators providing in-kind contributions.

PROJECT LEAD: Corey Clarke (Parks Canada)

PROJECT TEAM: Betty House (ACFFA); Tom Taylor (Cooke Aquaculture); Chris Bridger (Huntsman Marine Science Centre); Michael Beattie (NB – Agriculture and Aquaculture); Tim Robinson (Fort Folly First Nations); John Whitelaw (DFO)

COLLABORATORS: Atlantic Canada Fish Farmers Association; Cooke Aquaculture; Fisheries and Oceans Canada (DFO); Fort Folly First Nation; Huntsman Marine Science Centre; New Brunswick Department of Agriculture and Aquaculture

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Stocking the conservation sea cages with wild inner Bay of Fundy Atlantic Salmon smolts. Photo: Parks Canada

ATLANTIC SALMON SELECTION AND BROODSTOCK DEVELOPMENT PROGRAM FOR USE IN COMMERCIAL SALTWATER AQUACULTURE PRODUCTION ON THE EAST COAST OF CANADA

The overall goal of the Atlantic Salmon Performance Selection and Broodstock Development Program is to assess genetic variability of commercially relevant traits and improve commercial productivity.

Atlantic Salmon individuals and families with superior attributes for commercially important traits are selected to establish a pedigreed line. Up to 86 families are created each year using a partial factorial mating design to create half-sibling links between families. The partial factorial design also helps to maximize genetic variation. Half-sibling genetic links are necessary to assess the amount of variability in measured traits and the effects of genetics versus environment. Individual salmon from known families are PIT tagged to create a communally reared breeding nucleus as well as to conduct short-term challenges. Individuals from the same families are also reared in commercial sea cages to complete harvest assessments. To date, 300 families have been created and PIT tagged from four year classes. Genetic variation and heritability are assessed for all traits of interest prior to individual and family selection to create the next generational year class using a Total Merit Index. For instance, total body weight (growth) was assessed for 41,918 individuals from two year classes, 132 families, 67 sires and 77 dams which resulted in an estimated heritability of 0.27 at 2.5 years. This is within the range of published heritabilities for Atlantic Salmon from different geographic locations.

OCT. 2010–SEP. 2015

FUNDED BY: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund (ACOA-AIF)

CO-FUNDED BY: New Brunswick Innovation Foundation; Northern Harvest Sea Farms; Huntsman Marine Science Centre

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PROJECT TEAM: Susan Hodkinson, Chris Bridger (Huntsman Marine Science Centre); Jane Tosh (U Guelph); Aaron Craig, Robin Muzzerall (Northern Harvest Sea Farms)

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www.huntsmanmarine.ca

EFFECTS OF FEEDING HIGH PLANT PROTEIN DIET ON GROWTH AND NUTRIENTS UTILIZATION OF GROWTH-HORMONE TRANSGENIC DIPLOID AND TRIPLOID ATLANTIC SALMON (*SALMO SALAR* L.)

Previous studies have shown that transgenic (TG) Atlantic Salmon (*Salmo salar* L.) grew significantly faster and consumed less feed than non-transgenics (NTG). Moreover, the limited supply of fishmeal (FM) and fish oil from wild fisheries highlights concerns for the sustainable and responsible development of aquaculture production. The goal of this project was to assess the ability of juvenile diploid (2N) and triploid (3N) TG, and NTG Atlantic Salmon to use high plant protein (PP) diets. Triplicate groups of 2N/NTG, 3N/NTG, 2N/TG and 3N/TG salmon (30 g) were reared in freshwater and fed two isoproteic, isolipidic, and isoenergetic diets containing either high PP (68% PP) or high FM (36% PP) until achieving 400% growth. At the end of the experiment, TG salmon exhibited increased growth rates regardless of ploidy and diet compared with the NTG salmon. Food conversion ratio was reduced in TG (20–25% less) due to improved protein gain and retention efficiencies compared to the NTG. Protein, lipid, and energy digestibility was high for all the groups when compared to the reported values. Likewise, TG and NTG final body composition was similar to the values reported for the same size. More emphasis is currently placed on the optimization of cost effective feeds for triploid transgenic Atlantic Salmon.

The results of the present study indicate that 2N TG and 3N/TG Atlantic Salmon have the ability to maintain accelerated growth even when fed a high plant protein diet (68%), which may have important benefits for the optimization of production of transgenic Atlantic Salmon.

MAY 2012–MAY 2013

FUNDED BY: Atlantic Canada Opportunities Agency-Atlantic Innovation Fund (ACOA-AIF)

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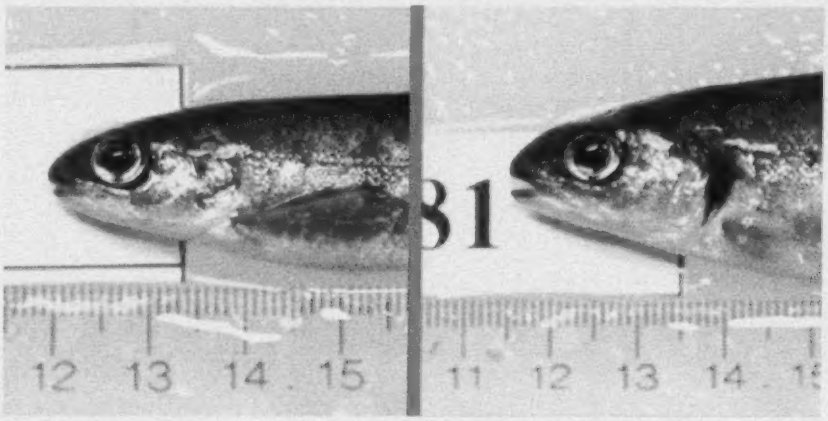
THE EFFECT OF OPERCULAR DEFORMITY ON FISH WELFARE AND AEROBIC CAPACITY



Juvenile salmon with complete operculum (left) and short operculum with exposed gill filaments (right). Photo: Tillmann Benfey (UNB)

Culling fish represents an economic loss, so anything that can be done to minimize the number of fish culled will help to sustain the industry. This research will also determine whether opercular deformities affect fish welfare.

As part of routine stock management, salmon farmers selectively cull fish with visible deformities in spite of there being, often, no clear evidence that these fish fail to thrive under controlled aquaculture conditions. For instance, fish with short opercula (i.e., gill covers), which are easily spotted because of their visible gills, often appear to be in good condition otherwise, based both on their size and weight-to-length ratio. Culling such fish may represent a needless economic loss. Fish with short opercula lack the opercular flaps necessary for maintaining unidirectional water flow across their gills, and therefore have diminished oxygen extraction efficiency and, by extension, reduced aerobic capacity. Although this would be a concern for wild fish with respect to activities such as migration, prey capture and predator avoidance, it is unclear whether it matters to farmed salmon. The objectives of this project are therefore: (1) to follow tagged juvenile Atlantic salmon with varying degrees of opercular shortening through time to see how this affects their survival and growth; (2) to assess the aerobic capacity of these same fish using standard physiological tests; and (3) to determine how genetics (family effects) influence these measured variables.

JUL. 2014–DEC. 2014

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC) Partnerships Program – Engage Grant

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ANALYSIS OF THE INCIDENCE OF ATLANTIC SALMON DEFORMITIES IN PRODUCTION – ENVIRONMENTAL OR GENETICS?

Discerning the effects of environmental and genetic factors on the occurrence and prevalence of deformities in Atlantic Salmon production will inform commercial producers of relevant factors under their production control and the importance of appropriate individual and family selection within broodstock programs. Reducing deformities in production stocks will improve fish welfare and decrease downgrades at harvest.

Various deformities/abnormalities are often evident in Atlantic Salmon commercial production. The occurrence and prevalence of many of these deformities are often believed to be the result of environmental conditions but the influence of genetics is not well understood. This project standardizes early rearing environmental effects between family specific combi tanks and recirculation systems – density, feeding, temperature, saturated oxygen, mg per liter of oxygen, pH, CO_2, alkalinity, total ammonia, nitrite/nitrate, and total gas pressure. A random group of progeny is assessed for type and prevalence of various deformities within each family when individuals are a 5 g minimum size. Skeletal deformities assessed include: short opercula, abnormal jaw or head, and spinal curvature. Irregularities associated with eye issues, missing fins, short fins, and eroded fins are also recorded. All recorded information (including normality) is noted and included in the analysis to determine whether occurrence prevalence can be attributed to environmental effects such as tank density or other factors. Nearly 94,000 Atlantic Salmon from 300 families over four year classes have been assessed to date to determine the effects of various environmental and genetic factors on variability and heritability in the prevalence of a specific deformity or combinations of deformities.

OCT. 2010–SEP. 2015

FUNDED BY: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund (ACOA-AIF)

CO-FUNDED BY: New Brunswick Innovation Foundation; Northern Harvest Sea Farms; Huntsman Marine Science Centre

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DETERMINATION OF THE POTENTIAL SPATIAL OVERLAP AND INTERACTION BETWEEN COMMERCIAL FISHERIES (AMERICAN LOBSTER, SNOW CRAB) AND FINFISH AQUACULTURE ACTIVITIES IN CONNAIGRE BAY, NEWFOUNDLAND

The outcomes of this project will provide valuable information that will inform future site development initiatives and contribute to the sustainability of the fishing and aquaculture industries on the south coast of Newfoundland and Labrador.

There is rarely an opportunity to collect and compare ecological data before, during, and after a salmon farming site has been approved and under production. This four year project will allow for the collection of environmental and biological data at two newly approved salmon aquaculture sites in Connaigre Bay, Newfoundland and Labrador – a bay that has not yet held salmon production sites. Pertinent data will be collected prior to the sites being established and during the full production cycle, as well as during the fallow period. In the siting area, there is particular concern for alterations to crab and lobster habitat and resulting changes in habitat utilization. As a result, this research will also examine potential changes in the benthic environment that could potentially impact lobster and snow crab populations. The ultimate goal of the research project will be to identify any measurable impacts caused by the introduction of fish farming on the commercial species currently harvested in Connaigre Bay.

APR. 2012–JUN. 2017

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Fish, Food and Allied Workers (FFAW); Cold Ocean Salmon Inc.

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

REDUCTION OF AMMONIA AND SOLIDS FROM CHINOOK SALMON CULTURE FACILITIES

Metabolic processes in farmed fish, as with all animals, produce wastes. Some of these are nitrogenous, principally ammonia, and they are released into the environment. Increases in nitrogen can occur with a decrease in the efficiency with which feed is utilized by the fish for growth and maintenance. The release of nitrogenous wastes into the environment can have implications for both the ecosystem and for the fish farming facility from which it is being released. Excess nitrogen release represents a potential economic loss in that it is an indication that feed is not being fully utilized by the cultured fish. The excess release can also result in regulatory consequences for culture facilities. Regulators and industry alike are looking for best practices to help reduce the greater levels of these compounds that can be found near farm sites.

This project will explore how feed regimes designed to stimulate compensatory growth may be used to reduce nitrogen excretion into the environment during Chinook Salmon production. Adequately exploiting compensatory growth using alternating periods of feed deprivation and re-feeding has the potential to reduce the excretion of nitrogenous wastes from the fish in culture facilities into the environment while increasing better feed utilization by the cultured fish. This research will help improve the ecological sustainability of Chinook Salmon reared in seawater and may be applicable to the culture of all salmon species.

APR. 2012–SEPT. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Agrimarine Industries Inc.

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DEVELOPMENT OF HIGH PERFORMANCE CHINOOK SALMON STOCKS FOR COMMERCIAL AQUACULTURE: GENETIC HYBRIDIZATION TO MAXIMIZE CULTURE EFFICIENCY AND MINIMIZE ENVIRONMENTAL IMPACT

The optimized commercial hybrid stocks, calibrated for variation in rearing conditions, will be marketed domestically and internationally, supporting the economic and environmental development of Canada's large and growing aquaculture. The research will also address important questions in the conservation of salmonids.

Salmon farming is one of Canada's growing industries and is extremely valuable. However, salmon farming must balance production economics with environmental impacts. Farmed Chinook Salmon are a valuable niche market with substantial growth potential, coupled with lower perceived environmental concerns (being a native species); however, their performance has not been systematically assessed. We are developing a performance-enhanced hybrid Chinook salmon stock with higher survival and growth and reduced feed costs. The new stock will use less wild-sourced lipid and protein for feed and minimize drug and chemical use for disease control, thereby minimizing the environmental footprint. The project will generate data on Chinook Salmon production stocks that will serve to improve salmon farming efficiency, which will help make Canada a global leader in Pacific salmon farming. Performance is being measured in offspring from crosses between inbred farmed and wild stocks. These offspring are expected to exhibit hybrid vigour, analogous to hybrid corn lines. We are examining molecular, physiological, and behavioural aspects of growth, survival, and flesh quality.

OCT. 2013–OCT. 2016

FUNDED BY: Natural Sciences and Engineering Council of Canada (NSERC)

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Yellow Island Aquaculture Ltd. net pens near Quadra Island, British Columbia. Photo: Trevor Pitcher (U Windsor)

DETECTING HYBRIDIZATION AMONG WILD AND FARMED ESCAPED ATLANTIC SALMON IN SOUTHERN NEWFOUNDLAND: FIELD COLLECTIONS

The monetary value of aquaculture production has now surpassed the total value of wild fisheries. Balancing the rapid industry expansion with environmental sustainability remains a challenge, with impacts for both wild populations and industry production. Aquaculture escapees represent a continued threat to the genetic integrity of wild populations, and have been shown to interbreed with wild fish, eroding local adaptation. In southern Newfoundland, wild Atlantic Salmon populations remain at record lows and are considered threatened by COSEWIC. Potential impacts associated with the developing aquaculture industry cannot be ruled out as contributing factor. The aim of the present study is to collect young of the year Atlantic Salmon following a large (>20,000 individuals) escape event in 2013 in southern Newfoundland. This escape event was equal to or greater than the estimate of wild salmon abundance in the region. Given the magnitude of this release event, and reports of mature escapees in freshwater, these samples are expected to contain a mixture of wild and hybrid individuals. Future genomic screening of these samples will be used to quantify the rates of successful hybridization and evaluate the potential genetic impact of aquaculture escapees on wild populations in Newfoundland and Labrador.

AUG. 2014–SEP. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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THERMAL AND pH TOLERANCE OF FARMED, WILD, AND FIRST GENERATION FARMED-WILD HYBRID SALMON

The results of this research will help to provide information on the potential impact of farmed escapees on wild stocks.

In Newfoundland and Labrador (NL), all farmed Atlantic Salmon (*Salmo salar*) originate from the Saint John River strain (New Brunswick). It is believed that wild stocks have developed adaptations to the local environment therefore the vulnerability of these local, genetically distinct stocks to farmed escapees through interbreeding is a concern. Farmed salmon escapees may share breeding grounds with wild counterparts, potentially interbreed and produce hybrids which might be poorly suited to survive in the wild. This in turn could impact the overall fitness and survival of the local wild salmon stocks. Studies on interactions between wild and farmed salmon have shown that this issue is area-specific and therefore these interactions need to be further explored within Newfoundland and Labrador.

This project will examine the effect of genetic origin on the environmental tolerance and fitness of wild, farmed, and first generation hybrid (F1 farmed-wild crosses) juvenile salmon when exposed to low pH and low seawater temperatures. This will clarify the ability of these fish (in particular the F1 hybrids) to survive under local environmental conditions (i.e., reduced pH level of river waters and low spring seawater temperatures) occurring in Newfoundland and Labrador.

APR. 2014–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon; Northern Harvest Sea Farms NL Ltd.

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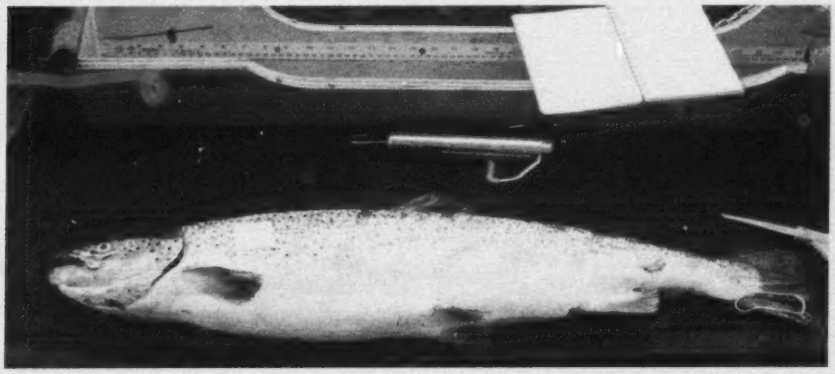
INVESTIGATION OF FARM-ORIGIN ESCAPED ATLANTIC SALMON IN NEWFOUNDLAND



Escaped farmed Atlantic Salmon captured in Garnish River, Newfoundland, in May, 2013. It is being sampled for biological characteristics and subsequent scale and genetic analysis. Photo: Chris Hendry (DFO)

Information collected in this project will aid in management of escapes from Atlantic Salmon aquaculture and inform methods for removal of escapes and minimizing impacts on wild Atlantic Salmon and other species.

Atlantic Salmon aquaculture production has grown steadily in Newfoundland and Labrador in the past decade from aproximately 3000 tonnes in 2001 to 22,196 tonnes in 2013. Concerns about genetic and ecological effects of escaped fish on wild populations of Atlantic Salmon and other species exist but little local empirical information is available. DFO is managing experimental fisheries for farm-origin escaped fish, collecting biological characteristics samples, and actively responding to reports of observations of suspected escaped farm-origin salmon in inland and coastal waters of the South Coast. Information on distribution, feeding, survival, life history stage, reproductive status, and cataloguing of gross morphological characteristics is being collected to aid in the development of an identification guide to accurately discriminate farmed and wild origin salmon and to guide escape incident response and recovery efforts to minimize potential environmental effects.

OCT. 2013–ONGOING

FUNDED BY: Fisheries and Oceans Canada (DFO)

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DEVELOPMENT OF A LOW DENSITY SNP ARRAY FOR PARENTAGE ASSIGNMENT IN ATLANTIC SALMON

The Centre for Aquaculture Technologies Canada (CATC) was established in 2012, with a focus on the use of advanced technologies to improve aquaculture productivity. Recognizing the need for rapid and cost-effective parentage assignment in fish, CATC endeavored to develop a low-density panel of 96 single nucleotide polymorphisms (SNPs) to assign parentage in Atlantic Salmon. The benefits of using the CATC low density SNP genotyping platform include adaptability for high-througput analysis, flexibility, and user specificity at a relatively low cost per sample.

SNP loci previously identified for Atlantic Salmon and two SNPs intended to detect the presence of the male-specific gene conserved amongst salmonids were selected for the array. Results of the validation work including more than 2500 full half sibilings from 57 families showed that a minimum of 69 SNPs could be used to determine parentage and genetic sex with 99% accuracy. The additional space on the array can be used for user-specific markers.

The use of a low density SNP array allows cost-effective, automated, genotyping of Atlantic Salmon for support of selective breeding programs, tracability, and management of wild populations. Most importantly, the relatively low cost encourages end users to apply the results of decades of salmon genomics research.

CATC is now offering this SNP genotyping service to other Atlantic Salmon producers and breeders. Now that the SNP panel has been tested and validated, the same technology can be applied to stock assessment, traceability, and monitoring of wild populations.

OCT. 2013–FEB. 2014

FUNDED BY: PEI Aquaculture and Fisheries Research Initiative Inc. **CO-FUNDED BY:** Natural Sciences and Engineering Research Council (NSERC) Industrial Post-Doctoral Award

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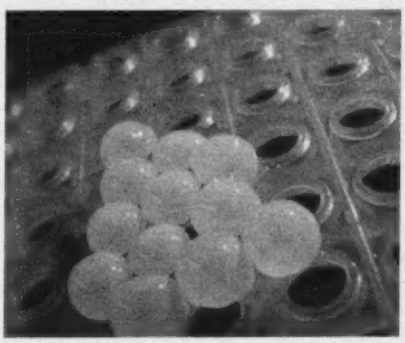
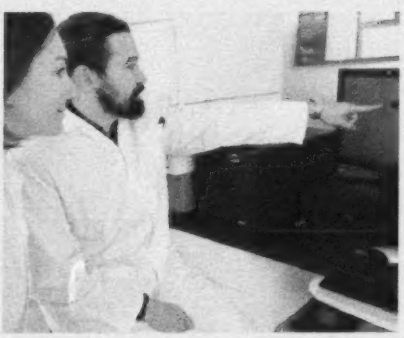


Eyed eggs. Photo: Valerie Barbosa



Center for Aquaculture Tecnologies Canada (CATC) staff. Photo: Berni Wood Photography

DEVELOPMENT OF QUANTITATIVE HISTOLOGICAL METHODS FOR UNDERSTANDING THE BONE METABOLISM OF FISH AND PREVENTING THE OCCURRENCE OF VERTEBRAL ANOMALIES IN FARMED SALMONIDS

The goal of our work is to contribute to the formulation of new low-phosphorus feeds and to provide preliminary tools to facilitate the selection of superior-performing, less polluting trout strains.

The occurrence of vertebral anomalies linked to nutritional deficiencies in intensive salmonid culture has negative impacts, both on production yield and on fish health and well-being. The early signs of chronic phosphorus deficiency in the Rainbow Trout include the development of small, widely spaced or biconcave vertebrae. Development of new quantitative histological methods (see figure) for analyzing the morphology, mineralization, and structure of various vertebral tissues may assist in differentiating certain bone mechanisms based on the nature of the anomaly observed. In individuals developing spaced vertebrae, production of nonmineralized (osteoid) matrix apparently continues during a deficiency episode, allowing the vertebrae to become mineralized after the situation returns to normal. In individuals with biconcave vertebrae, which tend to evolve into more severe anomalies (compressed vertebrae), bone mineralization appears instead to continue to the detriment of other bone remodelling mechanisms. Based on these outcomes, some individuals may have a better strategy for coping with phosphorus-deficiency episodes. If these various phenotypes could be correlated with specific genotypes, our results could lead to the identification of selection criteria for fish strains that are less inclined to develop skeletal anomalies.

SEP. 2010–AUG. 2014

FUNDED BY: Ministère du Développement économique, de l'Innovation et de l'Exportation – Programme de soutien à des initiatives internationales de recherche et d'innovation (PSIIRI) **CO-FUNDED BY:** DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP); Société de recherche et de développement en aquaculture continentale Inc. (SORDAC); Ressources Aquatiques Québec (RAQ) – Programme de bourse FONCER; Université Laval – Programme de bourse du Bureau International

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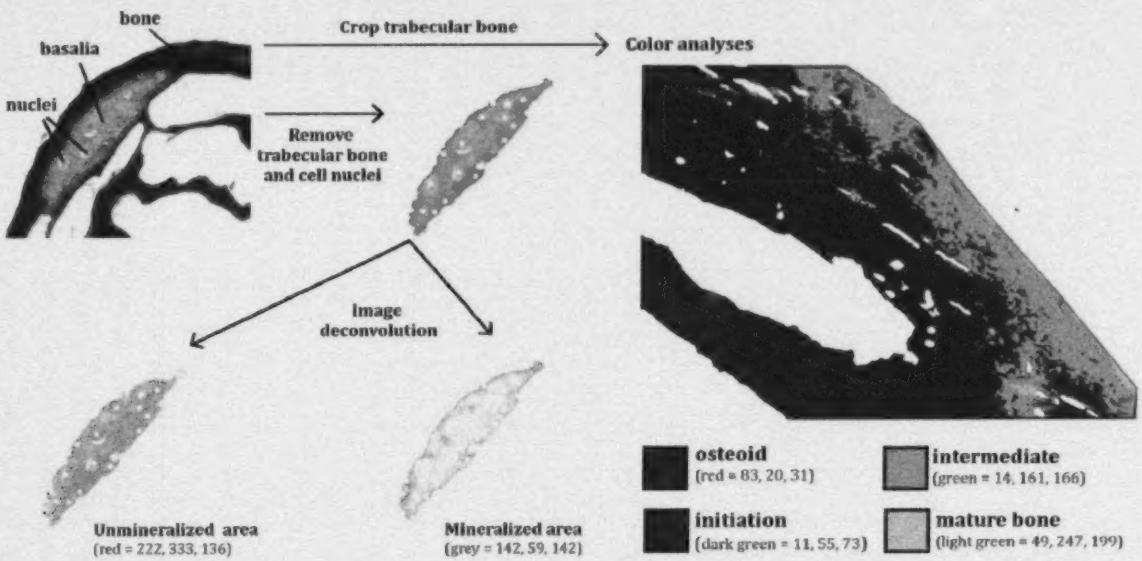

Schematic depiction of image analysis techniques developed in the laboratory for measuring the mineralization of basalia and the trabecular bone based on Sirius red-stained longitudinal sections (200x) of trout vertebrae. Photo: Marie-Hélène Deschamps (U Laval)

REPRODUCTION TRIALS BETWEEN WILD AND FARMED SALMON

The Atlantic Salmon currently farmed on the south coast of Newfoundland and Labrador originate from the Saint John River, New Brunswick, strain fish. The introduction of this non-native strain of the species had raised the question of the potential impact that escapes of these cultured fish might have on wild stocks. This study aimed to determine the potential mating success between mature farmed fish and wild fish from local Newfoundland river stocks by performing artificial crosses between the two groups.

Wild gametes (eggs and sperm) were found to be of higher quality (larger egg mass and diameter; higher overall energy availability) when compared to those from farmed fish. Hybrid crosses (wild-farmed) displayed higher fertilization rates than wild-wild or farmed-farmed crosses, with the highest fertilizations rates observed when the eggs originated from wild females. However, survival of these hybrid crosses was lower when compared to wild-wild crosses. Additionally, river water (e.g., pH) was not found to be a physical barrier to the eggs and sperm of farmed fish.

While the crosses performed were completely artificial, this research contributes to an increased understanding of the potential effects of interactions between escaped farmed salmon and their wild counterparts. Future studies on the survival and fitness of first and second generation hybrids in river conditions must be completed to ensure an accurate understanding of the outcome of these potential interactions.

APR. 2010–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Gray Aqua Group Ltd.

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MIGRATION TIMING AND DISTRIBUTION OF JUVENILE SALMON IN DISCOVERY ISLANDS AND JOHNSTONE STRAIT

This research will help explain how juvenile salmon utilize the Strait of Georgia, including the Discovery Islands area, with a focus on Fraser River Sockeye Salmon and to a lesser extent, Chinook Salmon. It will also provide the information required to fully assess the risks of disease transfer from salmon farms to the wild, understand the potential consequences of such transfers, and inform farm management policies.

Purse seines and DFO trawl surveys have greatly increased the understanding of the migration and health of juvenile salmon within the Strait of Georgia, BC, especially for Sockeye Salmon. Surveys conducted in 2010–2012 revealed that Fraser River Sockeye Salmon do not enter the Discovery Islands area (a fish farming area) until the end of May, and that they are widely distributed throughout this area for at least part of June. To further assess risks associated with interactions between farmed and wild fish, information in the following key areas is needed: (1) knowledge of migratory pathways of salmon and the duration of their residency in the vicinity of fish farms; (2) knowledge of the prevalence of pathogens and diseases within wild and farmed populations; and (3) knowledge of environmental and host conditions during the periods wild salmon reside in the vicinity of fish farms. Additionally, more information is required to further understand when and for how long juvenile salmon are present in the vicinity of fish farms, as well as to describe migration timing of juvenile Fraser River Sockeye Salmon out of the Strait of Georgia. To gain this required information, sampling will be performed using a three-year trawl survey in the Strait of Georgia and a three-year purse seine combined with hydroacoustic surveys in Johnstone Strait.

APR. 2014–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Marine Harvest Canada Inc.; Grieg Seafood BC Ltd.; Cermaq Canada

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INDIVIDUAL AND FAMILY RESISTANCE TO BACTERIAL KIDNEY DISEASE IN SAINT JOHN RIVER STRAIN ATLANTIC SALMON

Atlantic Salmon resistance to Bacterial Kidney Disease (BKD; causative pathogen *Renibacterium salmoninarum*) will improve fish health, welfare, growth, and survival. Selection for resistance will also reduce the need for antibiotic treatments in stocks that are BKD positive.

BKD is a consistent and reoccurring pathogenic problem that arises throughout the Atlantic Salmon aquaculture industry on a yearly basis. No method presently exists to successfully remove the pathogen completely despite use of various strategies to cope with BKD. In our study, individual Atlantic Salmon were intraperitoneally injected with BKD from Bay of Fundy Field Isolate FFA-198 (Research and Productivity Council, Fredericton). In the first challenge, 1037 Atlantic Salmon representing 48 families were injected. The study was terminated when mortality subsided at 40 days post injection (59.4% cumulative mortality). The estimated heritability from this year class for days to succumb adjusted for total body weight was 0.28. Indirect Fluorescent Antibody Technique (IFAT) was completed on each of the 421 Atlantic Salmon remaining at study termination. Of these, 148 had IFAT scores of 0 indicating that the injected BKD might have effectively cleared (additional confirmatory testing is planned). From the following year class, 1304 salmon from 83 different families have also been challenged. This challenge lasted for 117 days with <50% mortality; however, survival variations between families are evident. Further data analysis will occur for this year class.

OCT. 2010–SEP. 2015

FUNDED BY: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund (ACOA – AIF)

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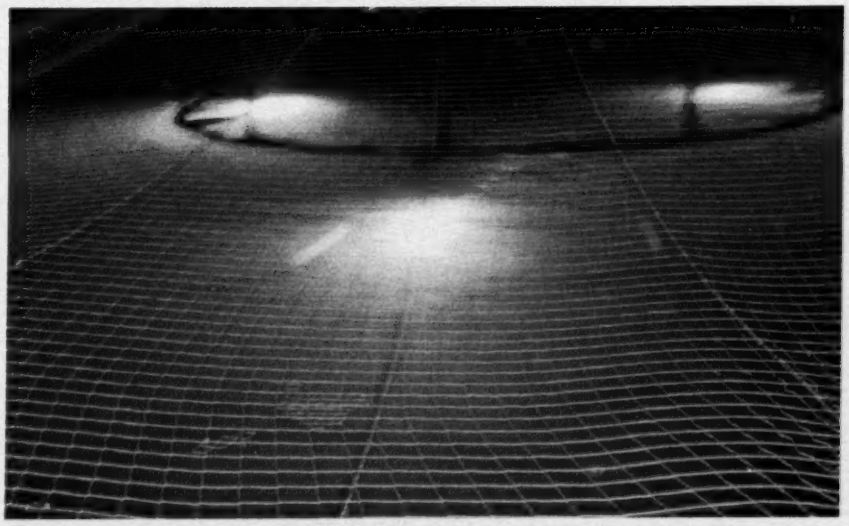
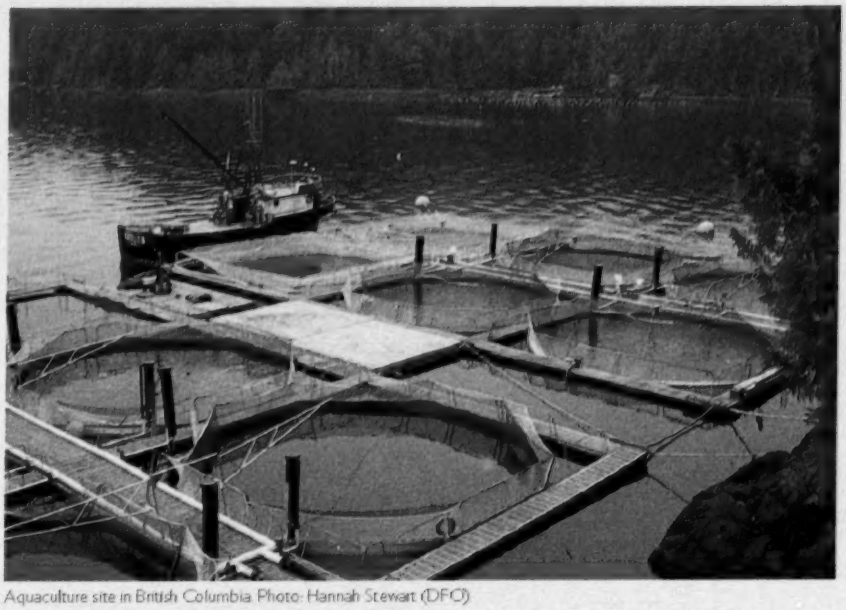
ECOLOGICAL EFFECTS OF BLUE LED LIGHTS USED AT MARINE FINFISH AQUACULTURE SITES IN BRITISH COLUMBIA

The use of artificial lighting within finfish aquaculture operations is a common technique used to delay sexual maturation and produce larger fish. Currently, finfish growers in British Columbia are interested in exploring the use of blue light emitting diode (LED) lights. These blue LED lights are more efficient, use less energy, and last longer than the traditionally used white metal halide lights, making them an attractive, economical choice. However, artificial lighting may affect both the diversity and abundance of the native organisms surrounding an aquaculture site, and this study evaluated these potential effects. The use of blue LED lights at an experimental site at night was found to attract fish and zooplankton, when compared to unlit controls. No statistical difference was observed for phytoplankton abundance (in the absence of blooms) or the settlement of benthic invertebrates between blue LED lights and controls. A commercial finfish site was also equipped with blue LED lights to determine their effects on fish maturation, growth, and sea lice counts in comparison to a site equipped with traditional white halide lights. There was no statistical difference in sea lice counts between farm sites equipped with blue LED lights or white halide lights, but direct comparisons were difficult. The results of this project have led to an increased understanding of the effects of blue LED lights on the native biota, but continued research is necessary in order to determine the effects and implications of blue LED lights directly at an aquaculture site. This information will allow both industry and Fisheries and Oceans Canada (DFO) to continue to support the sustainable development of finfish operations in British Columbia, and better manage the intricate relationship between aquaculture and the environment.



Artificial night lighting at an aquaculture site. Photo: DFO



Aquaculture site in British Columbia. Photo: Hannah Stewart (DFO)

APR. 2011–DEC. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Grieg Seafood

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COLLABORATORS: Grieg Seafood

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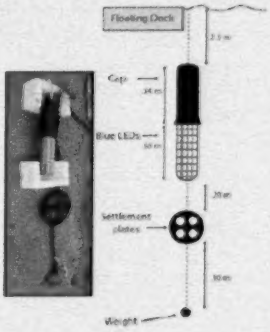
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm



Blue LED units attached to chain with weights to keep vertical. Photo: Hannah Stewart (DFO)

DEVELOPING STANDARD OPERATING PROCEDURES TO QUANTIFY SPERM DENSITY AND DILUTE OR EXTEND MILT FROM MALE SAINT JOHN RIVER STOCK ATLANTIC SALMON TO ENHANCE MANAGEMENT OF A BROODSTOCK PROGRAM

Unfertilized, poorly fertilized, or sub-optimally fertlized eggs result in lost revenue to the aquaculture industry. In addition, reducing the number of males present in a breeding population is a cost savings and also allows for more widespread use of higher ranked males (e.g., males having the highest estimated breeding values in a broodstock program).

Milt cryopreservation represents an essential technology to enhance commercial broodstock programs and live gene bank efforts. Products are available to dilute milt having high density so that a consistent milt-to-egg ratio is used and also to extend the life span of sperm cells well beyond the natural expectation. These products are regularly used elsewhere with Atlantic Salmon; however, methodical exploration on Saint John River stock Atlantic Salmon has not been completed. Our efforts chronicled use of an Atlantic Salmon calibrated photometer supplied by Cryogenetics to quantify sperm density from representative males from the Atlantic Salmon broodstock program at the Huntsman Marine Science Centre (HMSC). Results to date suggest a generally better fertilization rate using diluted milt compared with fresh milt. Diluted milt also fertilized a greater number of stripped eggs compared to standard industry practices using undiluted milt. Extending milt for up to 16 days is possible using the AquaBoost Extender and results showed similar fertilization rates between fresh diluted and extended milt. Extending milt presents time saving opportunities for a broodstock program as stripping milt is no longer necessary each day that eggs are collected. Genetic linkages will also be more manageable in a broodstock program requiring less frequent access to specific males.

OCT. 2014–MAR. 2015

FUNDED BY: NRC – Industrial Research Assistance Program (NRC – IRAP)

PROJECT LEAD: Amber Garber (HMSC)

PROJECT TEAM: Susan Hodkinson, Chris Bridger (HMSC); Maureen Ritter (Canada Cryogenetics Services); Jorn Ulheim (Cryogenetics)

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GENETIC AND GENOMIC IMPACTS OF ESCAPED FARMED SALMON IN ATLANTIC CANADA: EVALUATING THE USE OF ARCHIVED ATLANTIC SALMON SCALES AS A SOURCE OF PRE-IMPACT DNA

Aquaculture escapes represent a demonstrable threat to the persistence and stability of wild salmon populations, with impacts occurring through both genetic and ecological interactions. Direct genetic interactions result from interbreeding of farm escapes with wild fish, causing population-level changes including erosion of local adaptation and loss of fitness. However, the presence and magnitude of these genetic impacts are difficult to quantify in practice, largely due to a lack of pre-impact genetic baseline. Historically, monitoring activities for Atlantic Salmon have collected scales for aging purposes, and these archived scales could represent a powerful source of pre-impact DNA. The main objective of this project is to explore the use of various extraction methodologies to maximize DNA yield and estimate genotyping success rate from archived Atlantic Salmon scales. Extracted DNA will be quantified and used for preliminary microsatellite genotyping to demonstrate the utility of this approach. The ultimate goal is future comparison of pre- and post-aquaculture DNA samples from Atlantic Salmon in Atlantic Canada to quantify the presence and magnitude of genetic impacts due to escaped farmed salmon; thereby directly informing mitigation strategies through a quantification of impacts in space and time.

SEP. 2014–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Ian Bradbury (DFO)

PROJECT TEAM: Lorraine Hamilton, Patrick O'Reilly, Geoff Perry (DFO)

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SPATIAL AND TEMPORAL DISTRIBUTION AND SURVIVAL OF FARMED ATLANTIC SALMON AFTER EXPERIMENTAL RELEASE FROM SEA CAGE LOCATIONS

The expansion of the aquaculture industry in Newfoundland and the decline in wild salmon stocks have raised questions as to the possible impacts escaped cultured salmon may have on local wild populations. Despite increased industry awareness and the implementation of a code of containment, escapements still occur. Recently, escapements occurred in 2013 resulting in farmed fish recaptured in Garnish River and Little River (South Coast of Newfoundland), as well as in coastal waters. Research is needed to better understand the potential risk of escapees on wild salmon populations as spawning of aquaculture origin Atlantic Salmon has been demonstrated in international studies as well as in Canadian rivers in British Columbia and New Brunswick. The objective of this project is to determine the residency time, locations, migratory routes, and survival of escaped farmed Atlantic Salmon by monitoring the movements of groups of smolts, post-smolts, and adults in a simulated escape at different times of the year. Identification of the migratory routes followed by escapees, as well as residency patterns and how they vary with time of escapement (seasonal effects), will aid in designing more efficient recapture strategies.

The knowledge generated by this initiative will lead to improved and informed federal and provincial ecosystem-based environmental regulation allowing for the development of strategies to eventually lessen the impacts of escaped farmed Atlantic Salmon on the environment and wild salmon populations.

AUG. 2014–MAR. 2017

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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PROJECT TEAM: Brian Dempson, Keith Clarke, Curtis Pennell, Kimberley Burt, Lynn Lush, Geoff Perry (DFO)

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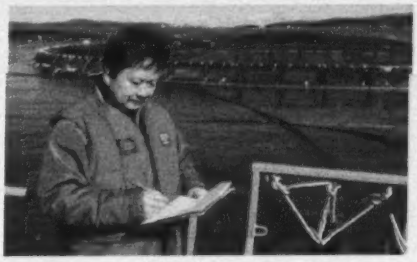
SALMON AND CHIPS: COMMERCIAL APPLICATION OF GENOMICS TO MAXIMIZE GENETIC IMPROVEMENT OF FARMED ATLANTIC SALMON ON THE EAST COAST OF CANADA

Aquaculture companies are increasingly incorporating genomics technologies into *their breeding programs in order to* develop desirable stock traits for improved growth and disease resistance. To retain its ability to compete internationally, Cooke Aquaculture/Kelly Cove Salmon (KCS) will partner with Elizabeth Boulding and her academic group from the University of Guelph to incorporate genomics marker technology into Kelly Cove Salmon's current breeding program. This will allow the company to improve the effectiveness of its breeding program and increase the resistance of its salmon to diseases and parasites.

The company aims to implement an advanced genomics micro-array



Cooke Aquaculture Inc.'s Keng Pee Ang at one of their New Brunswick sites. Photo: KCS

technology that compares single nucleotide polymorphisms (SNPs) known as SNP-chips. When blended with conventional animal breeding techniques, this can yield significant increases in the survival rates of eggs and juvenile stages, as well as improved saltwater performance. The implementation of this genomics technology is expected to increase the quality and sales of Kelly Cove's salmon, and improve profitability by reducing expenditures on vaccines and medication.

APR. 2014–MAR. 2017

FUNDED BY: Genome Canada, Genome Atlantic **CO-FUNDED BY:** NRC – IRAP

PROJECT LEAD: Keng Pee Ang (KCS); Elizabeth Boulding (U Guelph)

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RAPID GENOMIC SCREENING FOR ATLANTIC SALMON AQUACULTURE ESCAPEES AND HYBRIDS USING A HIGH THROUGHPUT NANOFLUIDIC DYNAMIC ARRAY

Atlantic Salmon cages in southern Newfoundland. Photo: Chris Hendry (DFO)

In Newfoundland, the cultivation of Atlantic Salmon has increased exponentially since the late 1960s. Coincident with this increased growth has been an increased incidence of farmed escapes and hence the likelihood of genetic interactions between wild and farmed Atlantic Salmon. Assessing the potential impacts of these escapes on wild salmon populations is complicated by the complexity of domesticated strains, including the potential use of European strains used to improve production. As part of this project, we are developing a panel of single nucleotide polymorphism (SNP) genetic markers. These will be used to quantify the genetic impacts of escaped farmed Atlantic Salmon on wild populations, as well as the frequency and geographic extent of interbreeding between domesticated and wild salmon.

Using existing genomics data, and new data generated from genome-wide scans, we are identifying a panel of markers that can be used to screen samples on a high throughput genotyping platform (i.e., Fluidigm nanofluidic dynamic array). This genomic screening tool will rapidly, accurately, and cost effectively quantify the presence of escapes, recent hybrids, and the extent of introgression into wild populations. This work is a first step towards identifying impacts of wild/farmed salmon interactions in Atlantic Canada and the development of appropriate mitigation measures.

SEP. 2014–MAR. 2015

FUNDED BY: DFO – Program For Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Ian Bradbury (DFO)

PROJECT TEAM: Lorraine Hamilton, Geoff Perry, Patrick O'Reilly, Dounia Hamoutene, Martha Robertson (DFO)

COLLABORATORS: Elizabeth Barlow (NL); Jon Carr (Atlantic Salmon Federation); Ross Hinks (Miawpukek First Nation)

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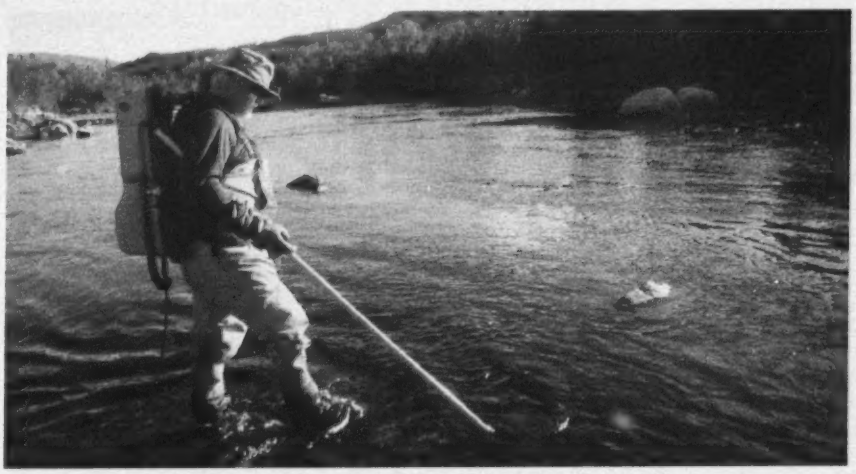

Sampling for possible offspring of escaped farmed Atlantic Salmon. Photo: Chris Hendry (DFO)

SUSTAINABILITY OF FISH FARMING: AN ECOSYSTEM APPROACH

Farming of fish and shellfish in the ocean is equal in importance to harvest fisheries as a means of seafood production. Concerns about disease and waste management, as well as interactions with commercial fisheries, has led to controversy among the industry, government regulators, and coastal communities. There are, however, many feasible environmental improvements for the culture of salmon in net pens.

Cooke Aquaculture, the largest locally owned aquaculture company in North America, has partnered with Dalhousie University, Canada's Ocean University, in a research program on aquaculture sustainability. Professor Jon Grant has been awarded the NSERC-Cooke Industrial Research Chair in Sustainable Aquaculture with research that includes simulation modelling. This approach is being employed using computer models and mapping of aquaculture ecosystems to predict the transport of diseases and waste particles by ocean currents. A field program of oceanographic instruments and sampling at coastal sites, including Cooke's farms, is being used to check the reliability of the predictions. Various planning scenarios are explored with this method, which can be used to arrange farm sites to minimize the spread of disease or accumulation of waste. At the local farm scale, these models will be used to test net designs to improve net security and healthy growing conditions for fish.

Dalhousie's capacity for aquaculture training of students will increase significantly as a result of this program, leading to a trained workforce for the aquaculture industry, and a new chapter in the practice of environmentally conscious fish farming.

JAN. 2014–JAN. 2019

FUNDED BY: NSERC **CO-FUNDED BY:** Cooke Aquaculture Inc.

PROJECT LEAD: Jon Grant (Dalhousie U)

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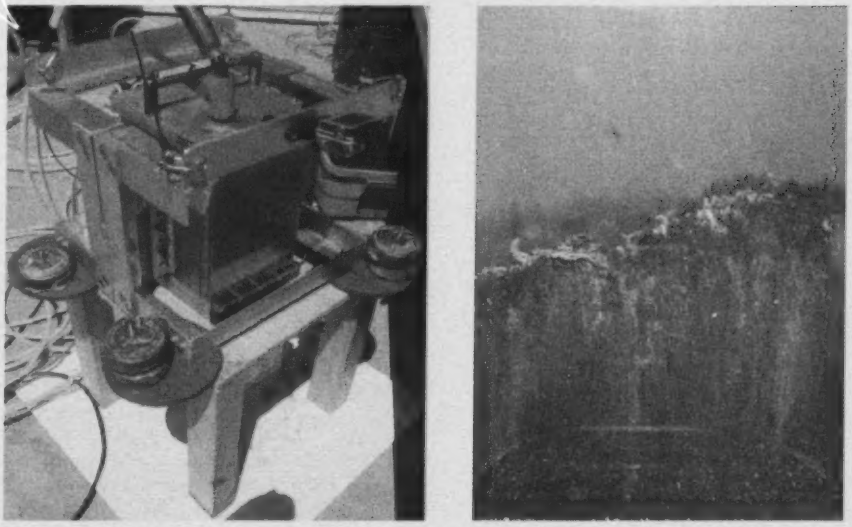
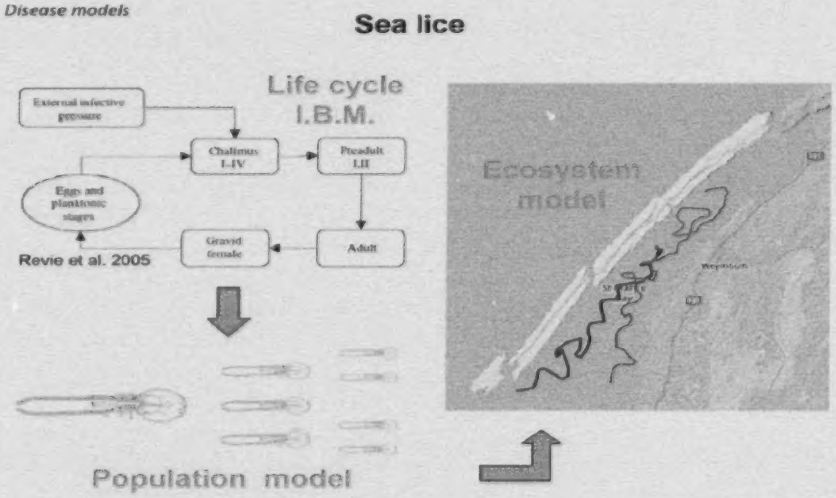


Sediment profile image device and image of coastal sediments used in assessing benthic health. Photo: Michelle Simone



Modelling scheme for simulation of sea lice dynamics in aquaculture

BETTER FEED FOR BETTER FISH: BIOMARKER PLATFORM FOR COMMERCIAL AQUACULTURE FEED DEVELOPMENT

The health of farmed salmon in Canada can be threatened by infectious diseases. The quality of feed can affect salmon health and impact their ability to withstand infection, but currently there is no way to measure how effective it is apart from growth rates – if fish grow bigger, faster, then presumably the feed is effective.

This project seeks to develop tools to better assess salmon health by examining their genes. Scientists at Memorial University of Newfoundland (MUN) and EWOS Innovation will jointly develop a platform to quantify the expression of multiple genes related to health and performance, using a single biological sample. The team will use genomics technologies to assess the effects of various diets on fish health at the molecular level. The highly-detailed information will help EWOS Innovation fine-tune feed formulas that include non-marine products, such as land-based plants, to maximize fish performance and to develop clinical feeds that will combat the diseases that are currently reducing salmon numbers. Within the life of this project, EWOS Innovation, one of the world's largest producers of aquafeeds, will be able to commercialize new, high-quality feeds that help to promote healthy fish.

The research will strengthen salmon aquaculture in Canada, in particular by reducing disease among farmed salmon. In addition, some project results will be shared as intellectual property, supporting growth in the sector. Finally, a focus on the use of Canadian raw materials in developing the feeds will also strengthen the feed supply industry.

OCT. 2014–SEP. 2017

FUNDED BY: Genome Canada; Genome Atlantic **CO-FUNDED BY:** EWOS Innovation

PROJECT LEAD: Richard Taylor (EWOS Innovation); Matthew Rise (MUN)

PROJECT TEAM: Simon Wadsworth, Adel El-Mowafi, Jason Mann (EWOS); Christopher Parrish (MUN)

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CYCLICAL FEEDING STRATEGY TO REDUCE ENVIRONMENTAL IMPACT OF MARINE SALMON FARMING

Compensatory growth, the rapid growth observed upon re-feeding after a period of food deprivation, has been associated with greater feed utilization (protein retention) for fish. Inducing compensatory growth of fish under culture conditions could require less feed for a given biomass gain, resulting in reduced loss of nitrogen and other by-products of feeding to the environment.

A trial was conducted with juvenile Chinook Salmon in seawater to ascertain the value of using a cyclical feeding (periodic withholding of feed) strategy to improve efficiency and reduce environmental impact of salmon farming. A commercial salmon feed was fed to Chinook under a variety of feeding cycles, including: daily feeding (control); 5 days feeding to satiation, 2 days no feeding; 7 days feeding, 7 days no feeding; 14 days feeding, 14 days half ration; and daily feeding at half ration.

Fish fed daily exhibited the best growth, but the weight gain of fish fed on a cycle of 5 days feeding 2 days no feed experienced was 89.2% of full fed fish, while feed consumption was only 81.9%. The improved feed efficiency could relate to a reduced level of nitrogen lost to the marine environment in the form of ammonia from salmon culture.

Improving the utilization of feed by salmon, at least at the juvenile stage, has the potential to reduce the environmental impact and improve the efficiency (cost per unit production) of salmon aquaculture. Extending the effect of improved efficiency with cyclical feeding to larger fish remains a challenge to be met with further research.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Aquaculutre Collaborative Research and Development Program (DFO – ACRDP)

PROJECT LEAD: Ian Forster (DFO)

PROJECT TEAM: Lawrence Albright, Robert Walker (Agrimarine); Biswas Biswajit, Mahmoud Rowshandeli (DFO)

COLLABORATORS: Agrimarine

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Biswajit Biswas feeding tanks of juvenile Chinook Salmon. Photo: Ian Forster (DFO)

SEA LICE

VARIATION IN SEA LICE SETTLEMENT WITHIN AND BETWEEN FAMILIES OF COMMERCIALLY REARED SAINT JOHN RIVER STOCK ATLANTIC SALMON

PREDICTING TRANSMISSION OF SEA LICE BETWEEN AQUACULTURE SITES IN THE EAST COAST OF CANADA

DEVELOPING A NON CHEMICAL MEANS TO EFFECTIVELY REMOVE ALL FORMS OF SEA LICE FROM AQUACULTURE SALMON USING WARM WATER

FIELD TESTING "GREEN TECHNOLOGY" SEA LICE TRAPS AND DOCUMENTING On-SITE DYNAMICS OF SEA LICE EARLY LIFE HISTORY

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN ENVIRONMENTAL PARAMETERS, OCEANOGRAPHIC ZONES OF INFLUENCE AND THE PREVALENCE OF PARASITIC COPEPODS ON THREE SPINE STICKLEBACK IN BAY DESPOIR, NEWFOUNDLAND WITH SPECIFIC REFERENCE TO SALMONID AQUACULTURE SITES

ASSESSING SENSITIVITY TO EMAMECTIN BENZOATE (SLICE®) IN SEA LICE *LEPEOPHTHEIRUS SALMONIS* FROM FARMED ATLANTIC SALMON IN BRITISH COLUMBIA

MONITORING AND MODELLING OF SEA LICE INTERACTION WITH WILD AND FARMED SALMON IN THE BROUGHTON ARCHIPELAGO

EVALUATION OF THE SEASONAL ABUNDANCE, PREVALENCE AND SPECIES DIVERSITY OF SEA LICE ON NON SALMONID MARINE FISH SPECIES FROM BAY DESPOIR, NEWFOUNDLAND, WITH SPECIFIC REFERENCE TO AREAS NEIGHBOURING ATLANTIC SALMON CAGE SITES

DEVELOPMENT AND PROGRESS OF THE CUNNER BREEDING PROGRAM

DEVELOPMENT OF BACTERIAL BIOMARKERS OF SALMON MICROBIOTA MEDIATED RESISTANCE AGAINST SEA LOUSE *LEPEOPHTHEIRUS SALMONIS*

THE EFFECTS OF SEA LICE IN MODULATING SALMONID SUSCEPTIBILITY TO VIRUSES

SEA LICE INFECTION LEVELS ON JUVENILE SALMON DURING EARLY SEAWATER RESIDENCY AND MIGRATION OUT OF THE STRAIT OF GEORGIA

DEFINING THE RISK OF SEA LICE INFECTIONS THROUGH THE DEVELOPMENT OF AN UNDERSTANDING OF THE EARLY LIFE HISTORY POPULATION DYNAMICS OF SEA LICE ASSOCIATED WITH ATLANTIC SALMON AQUACULTURE SITES IN THE BAY OF FUNDY

TRANSPORT AND DISPERSAL OF DISCHARGED SEA LICE CHEMICAL THERAPEUTANTS IN SOUTHWEST NEW BRUNSWICK

THE EFFECTS OF SINGLE AND REPEAT *LEPEOPHTHEIRUS SALMONIS* (SEA LICE) INFECTIONS ON THE HEALTH OF JUVENILE PACIFIC SALMON

BIOASSAYS WITH FARM COLLECTED SEA LICE FROM ALL NEW BRUNSWICK AQUACULTURE BAY MANAGEMENT AREAS USING ALL APPROVED SEA LICE TREATMENT OPTIONS

THE POTENTIAL OF USING NEWFOUNDLAND STOCK CUNNERS TO CONTROL SEA LICE (*LEPEOPHTHEIRUS SALMONIS*) ON INFECTED ATLANTIC SALMON SMOLTS: TANK TRIALS

DISEASE GENOMICS FOR SALMON LOUSE RESISTANCE IN A COMMERCIAL STRAIN OF ATLANTIC SALMON

VARIATION IN SEA LICE SETTLEMENT WITHIN AND BETWEEN FAMILIES OF COMMERCIALLY REARED SAINT JOHN RIVER STOCK ATLANTIC SALMON

Decreasing the settlement of sea lice on Atlantic Salmon using natural resistance will benefit the industry by increasing fish welfare, growth, and survival while decreasing the use of therapeutants and the number of downgrades at harvest.

The Atlantic Salmon aquaculture industry is seeking strategies to manage sea lice infestations throughout its marine operations. Chemical therapeutants are often used to remove sea lice from infected fish. However, non-chemical approaches are highly desired by the industry if they prove to effectively reduce the total farm load of sea lice. Exploiting natural resistance of Atlantic Salmon individuals and families to sea lice infection holds promise as a non-chemical means to reduce sea lice loads within commercial aquaculture settings. The Huntsman Marine Science Centre has used its established sea lice infection model to explore the natural variability of 2,227 individual Saint John River Atlantic Salmon to Bay of Fundy sea lice infection in challenges involving 132 families (67 sires and 77 dams) from two year classes. A high degree of variability to sea lice infection resistance is evident within and between families. The heritability of this trait was estimated to be 0.20. Results from these challenges will be used to determine the feasibility of integrating sea lice resistance into the selection scheme of a commercial Atlantic Salmon broodstock program.

OCT. 2010–SEP. 2015

FUNDED BY: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund (ACOA-AIF)

CO-FUNDED BY: New Brunswick Innovation Foundation; Northern Harvest Sea Farms; Huntsman Marine Science Centre

PROJECT LEAD: Amber Garber (Huntsman Marine Science Centre)

PROJECT TEAM: Susan Hodkinson, Chris Bridger (Huntsman Marine Science Centre); Jane Tosh (U Guelph); Aaron Craig, Robin Muzzerall (Northern Harvest Sea Farms)

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PREDICTING TRANSMISSION OF SEA LICE BETWEEN AQUACULTURE SITES IN THE EAST COAST OF CANADA

The objective of this study is to incorporate hydrological data into a statistical disease model to better predict farm-level infections and transmission patterns of sea lice on the east coast of Canada. Our work will help the industry establish a protocol for effective bay-management strategies thus, minimizing the effect on the environment while reducing production costs.

Infectious diseases of marine finfish can have a significant economic impact on the global aquaculture industry. Effective control measures against transmission of pathogens between marine farms are essential to reducing losses of fish from infectious diseases, production costs, and environmental pollution from therapeutic treatments. Farm-to-farm spread of pathogens in Atlantic Salmon aquaculture has been described at different distances in several countries, including Canada. However, we currently lack the understanding of the impact of coastal water movements (hydrology) on the transmission of pathogens. Increasing our understanding of transmission patterns in coastal waters will improve existing aquaculture management areas to allow for more effective coordinated treatment strategies in controlling for specific pathogens.

This project will incorporate both hydrological information and ongoing fish disease surveillance data to develop and validate statistical models for disease transmission patterns of sea lice in coastal waters on the east coast of Canada.

We hypothesize that hydrodynamic variation in space and time is a key driver of farm-level infections and transmission patterns. To explore this hypothesis we will focus on a parasite (sea louse) that continues to cause problems in the salmon aquaculture industry in southwestern New Brunswick.

MAY 2014–APR. 2015

FUNDED BY: Canada Excellence Research Chair (CERC) – Aquatic Epidemiology, UPEI

PROJECT LEAD: Raphael Vanderstichel (UPEI)

PROJECT TEAM: Fred Page (DFO); Erin Rees, Larry Hammell, Crawford Revie, Sophie St. Hilaire (UPEI)

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DEVELOPING A NON-CHEMICAL MEANS TO EFFECTIVELY REMOVE ALL FORMS OF SEA LICE FROM AQUACULTURE SALMON USING WARM WATER

Results of the project are expected to provide the required information for ongoing modification of the commercial sea lice warm water shower device, as well as inform sea lice management strategies.

The sea louse (*Lepeophtheirus salmonis*) is a globally acknowledged challenge for salmon farming operations and a considerable amount of resources are being expended to manage this pest. Chemo-therapeutants and animal husbandry practices have been traditionally used to keep these parasites under control, but there are now signs that sea lice are becoming resistant to many of the chemicals that are being used and recent studies have shown that some of these chemicals are lethal to non-target organisms. Consequently, many non-chemical alternative treatments for sea lice controls are being tested such as predators (cleaner-fish), traps (either physical or biological), and physical exclusion devices (nets, electrical fields). One of the more promising techniques being developed to remove sea lice from captive salmon is the use of warm water. Recent Canadian innovations have developed a warm water shower which appears to remove all attached stages of sea lice and also prevents the detached sea lice individuals from being returned to the ocean. This project aims to develop protocols for the best application of the warm water shower technique to safely and effectively remove sea lice from Atlantic Salmon, including an understanding of the mechanism involved in sea lice removal using warm water.

APR. 2014–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

PROJECT LEAD: Shawn Robinson (DFO)

PROJECT TEAM: Steve Neil (DFO); Keng Pee Ang (Kelly Cove Salmon Ltd.)

COLLABORATORS: Kelly Cove Salmon Ltd.

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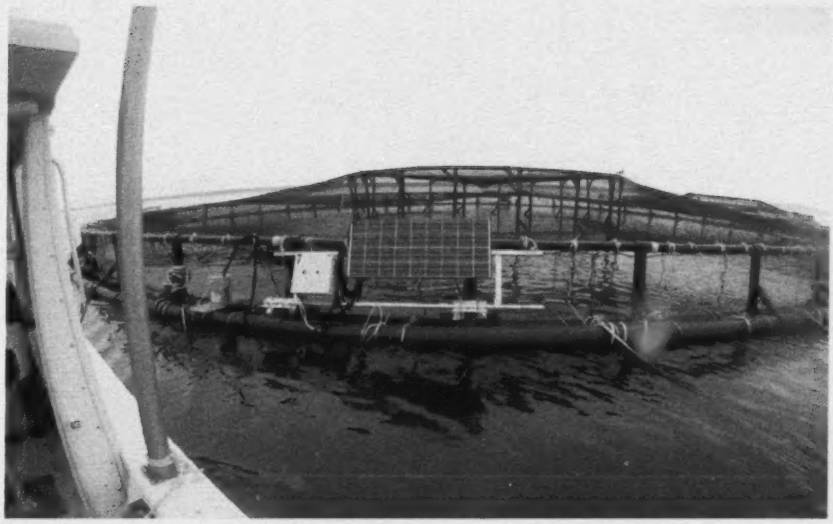
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

FIELD TESTING "GREEN TECHNOLOGY" SEA LICE TRAPS AND DOCUMENTING ON-SITE DYNAMICS OF SEA LICE EARLY LIFE HISTORY

The information gathered during this study on larval distribution and physical abilities indicated that there seems to be some significant interactions on site that may be retaining larvae. Further development is required for the light traps to be effective.

The sea louse, *Lepeophtheirus salmonis*, continues to be a global problem for salmon farming operations and studies have indicated that sea lice are starting to become resistant to therapeutants with continued exposure, thus there is a need for new approaches. There is also concern that operational practices at farm sites could be contributing to the magnification of sea lice infections on the salmon if control measures are not effective for all sea lice life stages (e.g., eggs, larvae). This field project tested the concept that physical light-based traps, in conjunction with an understanding of the on-site sea lice larval dynamics, can help to control sea lice populations. However, the traps were not successful in reducing sea lice densities within the salmon cages due to confounding effects of ongoing sea lice treatments on the site and a malfunction in the self-cleaning filters. The traps worked very well to continually monitor the larval levels and showed seasonal patterns of abundance. Lab studies revealed that egg strings were capable of successfully hatching without the female being present and resulting larvae were found to be very capable swimmers. Further research should look at combining light traps with another attractant to increase the efficiency of sea lice capture.



Solar powered sea lice light trap attached to a salmon cage in the Bay of Fundy. Photo: Nathaniel Feindel (DFO)

APR. 2012–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP)

CO-FUNDED BY: Kelly Cove Salmon Ltd.

PROJECT LEAD: Shawn Robinson (DFO)

PROJECT TEAM: Frank Powell (Cooke Aquaculture)

COLLABORATORS: Keng Pee Ang (Kelly Cove Salmon Ltd.)

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AN INVESTIGATION OF THE RELATIONSHIP BETWEEN ENVIRONMENTAL PARAMETERS, OCEANOGRAPHIC ZONES OF INFLUENCE, AND THE PREVALENCE OF PARASITIC COPEPODS ON THREE-SPINE STICKLEBACK IN BAY D'ESPOIR NEWFOUNDLAND WITH SPECIFIC REFERENCE TO SALMONID AQUACULTURE SITES

The results of this research will help provide information on the potential of wild non-salmonid fish species to act as sea lice reservoirs (with the potential to re-infect farmed fish), as well as a potential predictor of infestation levels in Bay Management Areas.

Salmonid farming in Newfoundland and Labrador (NL) has expanded rapidly over the past decade. Concurrently, the occurrences of sea lice infestation on farmed salmon are increasing in some bays (e.g., Bay D'Espoir and Fortune Bay). It has been suggested that non-salmonid species could act as sea lice reservoirs for future infections and/or could act as predictors for infection rates in wild and farmed fish in subsequent years. Despite this, very little information is available on the interaction of wild, non-salmonid fish species at aquaculture sites and sea lice outbreaks at these sites. Based on the results of a 2013 pilot study in Bay D'Espoir, NL, Three-Spine Stickleback were found to be the most prevalent wild fish species around aquaculture sites, and gill lice were the most abundant species of sea lice observed. Gill lice appear to be capable of completing their life cycle on Three-Spine Stickleback; however, the extent of its impact on farmed salmonids in NL has not been characterized. This project will investigate the potential correlation between the distribution of gill lice and other parasitic sea lice on Three-Spine Stickleback and farmed salmonids in the Bay D'Espoir region.

APR. 2014–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon Inc.

PROJECT LEAD: Harry Murray (DFO)

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ASSESSING SENSITIVITY TO EMAMECTIN BENZOATE (SLICE®) IN SEA LICE *LEPEOPHTHEIRUS SALMONIS* FROM FARMED ATLANTIC SALMON IN BRITISH COLUMBIA

As this research is the first effort to document sub-lethal effects of emamectin benzoate (SLICE®), a commonly used sea lice treatment. The results of this project will contribute to both increased knowledge and improved disease management strategies to help minimize the impacts of pathogens on farmed salmon.

Infestation with sea lice (*Lepeophtheirus salmonis*) is a significant economic burden to commercial salmon aquaculture. While there are a range of sea lice control strategies, in-feed emamectin benzoate (known commercially as SLICE®) is the treatment of choice for sea lice on farmed Atlantic Salmon because of its high efficacy and ease of application. However, recent treatment failures have been linked to resistance to SLICE® within sea lice populations. While *in vitro* data support the conclusion that sea lice in British Columbia remain sensitive to SLICE®, treatment efficacy is variable among sites. Sublethal effects of SLICE® are poorly documented and if this treatment is to remain an effective management strategy, it is important to determine its effects on treatment survivors and on sea lice prior to mortality. This project will attempt to forward that knowledge by: (1) assessing the hatch rate, developmental rate, and viability of cultured larval sea lice (*L. salmonis*); (2) generating first generation (F1 generation) sea lice to permit comparative assessments of SLICE® sensitivity with parental sea lice; and (3) performing biological assessments to determine the SLICE® sensitivity of parental and F1 generation sea lice, pre- and post-treatment, from each of three salmon production sites.

APR. 2014–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Marine Harvest Canada Inc.

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PROJECT TEAM: Amelia Mahoney (DFO); Brad Boyce, Diane Morrison (Marine Harvest Canada Inc.)

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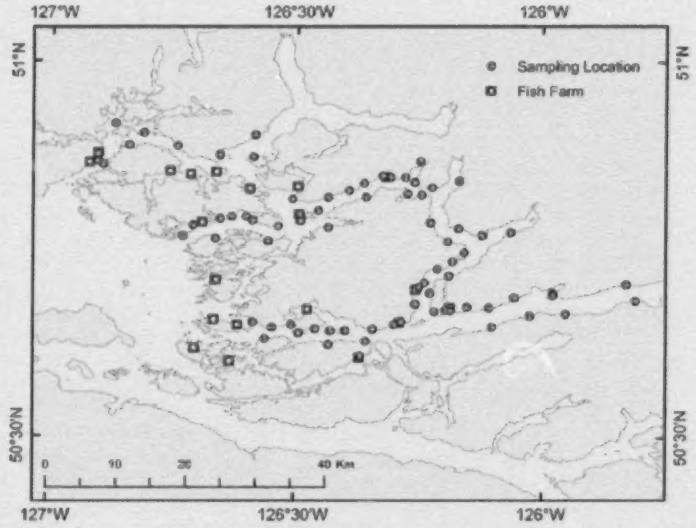
MONITORING AND MODELLING OF SEA LICE INTERACTION WITH WILD AND FARMED SALMON IN THE BROUGHTON ARCHIPELAGO

This project has helped to improve our understanding of the interactions of sea lice with wild and farmed fish. The results of this research will help inform decisions on the siting and management of finfish aquaculture sites in BC and support the long term health of wild fish populations and the fish farm industry.

The interaction of sea lice with farmed salmon and wild salmon has been the focus of international concern for at least a decade. Health and growth performance issues associated with sea lice infestations continue to be a significant concern for the salmon farming industry globally, driving the implementation of preventative measures in areas where there is the threat of infestation. This project developed a predictive model of the distribution of sea lice originating from fish farms and estimated the number of encounters of out-migrating salmon with sea lice. It also established statistically robust models to capture associations between the sea lice burden on wild fish and conditions on BC fish farms. Modelling was used to associate factors such as year, month, type of seine gear used, fish species, and fish length to the presence of sea lice on wild chum and pink salmon. Using Geographical Information Systems (GIS) software, trajectory maps (maps which show the direction and distance of particle movement) and particle density maps were generated for fish farm locations in the Broughton, as well as corresponding fish farm connectivity tables (tables which describe the overlap of particle exchange between farms).



The Broughton Archipelago area showing the locations of fish farms and the sites sampled during the 2012 monitoring program.

APR. 2012–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Marine Harvest Canada; Grieg Seafood BC; Mainstream Canada

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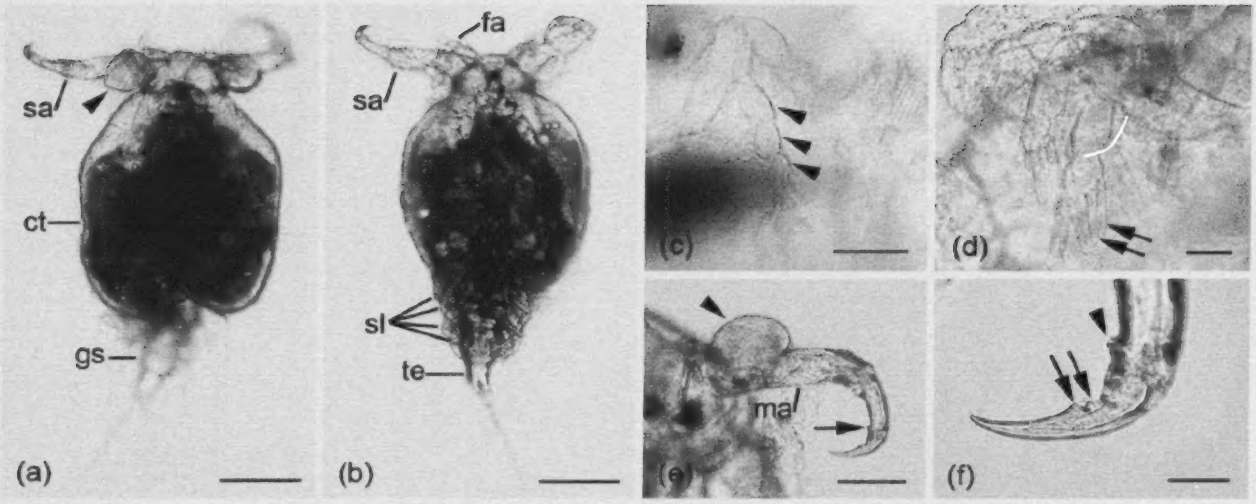
EVALUATION OF THE SEASONAL ABUNDANCE, PREVALENCE AND SPECIES DIVERSITY OF SEA LICE ON NON-SALMONID MARINE FISH SPECIES FROM BAY D'ESPOIR, NEWFOUNDLAND, WITH SPECIFIC REFERENCE TO AREAS NEIGHBOURING ATLANTIC SALMON CAGE SITES



Morphological characteristics of adult female *Ergasilus labracis* collected from the Three-Spined Stickleback, *Gasterosteus aculeatus*, in Bay d'Espoir, Newfoundland. Photo: Alexandra Eaves (DFO)

Although the copepod, *Ergasilus labracis*, has been listed as present in Newfoundland previously, it has a broad host range and has been reported to be pathogenic to farmed salmonids. Therefore, the potential impact of this parasite on wild and farmed fish populations around Newfoundland should not be underestimated.

This project was designed to evaluate the potential for wild non-salmonids to act as reservoirs for parasitic copepods on the South Coast of Newfoundland (Bay D'Espoir). Due to the expansion of finfish aquaculture on the south coast of Newfoundland in the last two decades, it is imperative to understand the parasite ecology of this region. It is known that many species of marine fish frequent areas around cage sites, including Atlantic Cod, pollock, herring, mackerel and sticklebacks (of at least three different species) including the Three-Spined Stickleback. As such, it is reasonable to hypothesize, based upon observations on the west coast of Canada, that many of these species might also be hosting economically important parasites like *Lepeophtheirus* spp. and/or *Caligus* spp. in Newfoundland bays where salmon farming is expanding and infestations have been reported in the past. Observations of *L. salmonis* on sticklebacks and other non-salmonid species thus may be used as a predictor of infestation levels within Bay D'Espoir and/or neighboring bays. The most common parasite surveyed during the project was *Ergasilus labracis* (n = 4684). Other parasitic copepods observed on sticklebacks during the survey included chalimus stage *Lepeophtheirus* spp. (n = 3), adult *Argulus alosae* (n = 2), and a single *Thersitina gasterostei*. These observations represent a new host record for *E. labracis*.

APR. 2013–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon Inc.

PROJECT LEAD: Harry Murray (DFO)

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DEVELOPMENT AND PROGRESS OF THE CUNNER BREEDING PROGRAM

Kelly Cove Salmon Ltd. Cunner. Photo: Roger Wysocki (DFO)

The use of a native species of cleaner fish, the Cunner, in Canadian salmonid aquaculture has the potential to significantly decrease the use of chemotherapeutants. The cleaner fish, such as Cunners and Lumpfish, are expected to be part of an Integrated Pest Management Program (IPMP).

Research on greener ways to control sea lice (*Lepeophtheirus salmonis*), a naturally-occurring ectoparasite, continues to be a priority for Kelly Cove Salmon Ltd. (KCS). Following field trials that showed the efficacy of the Cunner (*Tautogolabrus adspersus*) in controlling adult sea lice in cages and in the laboratory in 2011, additional Cunners were transferred to a hatchery at the Huntsman Marine Science Centre (HMSC) in St. Andrews in 2012. Significant progress has been made in all aspects of the breeding program since the first successful Cunner spawning in captivity in 2011. A substantial spawn in 2013 resulted in approximately 33,000 healthy juveniles.

With assistance/consultations from Memorial University (D. Boyce and staff) and Scotian Halibut Limited (B. Blanchard and staff), the 2014 spawning season saw improvements in broodstock health, egg collection, and live feed production. This, in addition to new methods of egg collection, resulted in 27 times more eggs collected in 2014 over 2013. From current larval stocks, approximately two to three times more 2014 F1 juveniles are expected. A portion of the 2013 F1 Cunners will be graded and transferred to commercial sea cages in 2015 for field trials on efficacy alongside wild caught Cunners. The remaining Cunners will become broodstock for studies on fecundity and viability of an F2 generation. The overall goal is a fully captive Cunner breeding program at KCS.

MAY 2012–DEC. 2015

FUNDED BY: NRC – Industrial Research Assistance Program (NRC – IRAP)
CO-FUNDED BY:
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DEVELOPMENT OF BACTERIAL BIOMARKERS OF SALMON MICROBIOTA MEDIATED RESISTANCE AGAINST SEA LOUSE *LEPEOPHTHEIRUS SALMONIS*

Sea lice, *Lepeophtheirus salmonis*, are naturally occurring parasites in sea water. Nevertheless, they represent an animal health issue for both wild and farmed salmon and can result in significant economic losses for the salmon aquaculture industry. There are a number of strategies currently being used by farmers to combat sea lice, including the use of chemicals. This has had mixed results and there are concerns about the effects of sea lice treatments on non-target organisms, including lobster.

Numerous research activities have been undertaken to better understand sea lice, their relationship to the marine environment and fish, and the treatments and methods used to reduce their abundance near wild and farmed salmon species. Researchers have been exploring new strategies, such as vaccines and novel drugs for the treatment and removal of sea lice from farmed fish. One innovative approach that is showing some promise is through the use of selective genetic breeding programs to harness the natural resistance to sea lice exhibited by some salmon families.

This study represents the first step in developing sea louse control strategies that combine selective breeding with a probiotic approach; treating farmed salmon with beneficial bacteria isolated from host microbiota that will help protect the salmon against parasites and pathogens. The long term objectives of this research support the development of a sustainable strategy to prevent infections transmitted or triggered via sea lice prevalence and sea lice landing.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.; Université Laval

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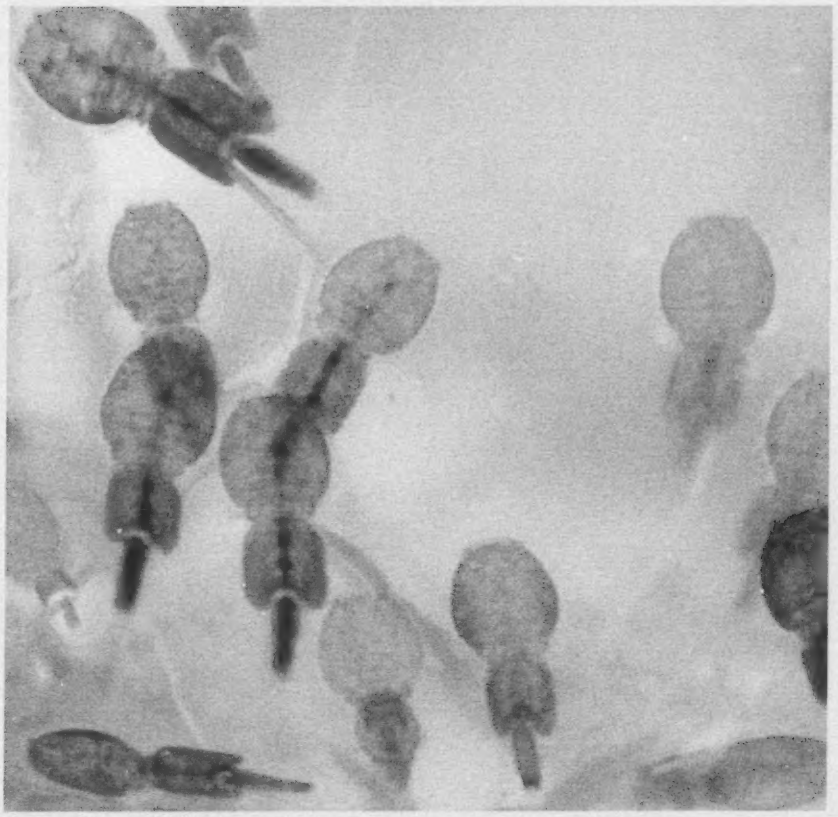
THE EFFECTS OF SEA LICE IN MODULATING SALMONID SUSCEPTIBILITY TO VIRUSES

The sea louse, *Lepeophtheirus salmonis*, is a serious pest of farmed Atlantic Salmon in both eastern and western Canada. As sea lice are ubiquitous in the marine environment and co-occur with endemic viruses, it is inevitable that mixed infections of sea lice and viruses occur on both coasts. Despite their widespread occurrence in both wild fisheries and aquaculture, there have been no controlled studies that explicitly examined the effect of *L. salmonis* on disease caused by viral pathogens. Infectious hematopoietic necrosis virus (IHNV) is a rhabdovirus that infects wild and cultured salmonid fish throughout the Pacific Northwest of North America. Infectious salmon anemia virus (ISAV) is an orthomyxovirus that infects and causes disease in farmed Atlantic Salmon in eastern Canada. For both viral pathogens, there is a need to better understand if sea lice parasitism is a predisposing factor that influences virus transmission and salmon susceptibility to infection. Our research addresses this issue by integrating parallel investigations into IHNV and ISAV interactions with sea lice in western and eastern Canada, respectively. Our goal is to determine an acceptable level of sea lice infestation at which intervention or pest management strategies may be needed to prevent further damage from viral infection.

This research will guide decision-making regarding the magnitude of sea lice management thresholds for use in salmon aquaculture.



The salmon louse, *Lepeophtheirus salmonis*

SEP. 2014–MAR. 2016

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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SEA LICE INFECTION LEVELS ON JUVENILE SALMON DURING EARLY SEAWATER RESIDENCY AND MIGRATION OUT OF THE STRAIT OF GEORGIA

There have been reports that suggest the poor returns of Fraser River Sockeye Salmon could be caused by infections with sea lice acquired from salmon farms during their northern migration from the Strait of Georgia. To determine the potential impact, if any, from salmon farms, background information is needed about the species of sea lice that are present and their numbers on juvenile salmon and non-salmonid hosts. This multi-year project involved sampling of juvenile salmonids and non-salmonids for sea lice during the out migration period. Samples were collected from numerous sites throughout the Strait of Georgia and Johnstone Strait to examine the role that salmon farms may play as a source of sea lice infections on wild fish. Prevalence and abundance of the different sea lice species and their developmental stages were determined. Samples of juvenile Fraser River Sockeye are also examined for the presence of other pathogens and disease. This project provides valuable information on: (1) the species composition and abundance of sea lice in these areas; (2) when and where fish become infected with sea lice; (3) whether patterns of sea lice infection vary among years; and (4) the overall health status of juvenile Fraser River Sockeye Salmon.

APR. 2010–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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DEFINING THE RISK OF SEA LICE INFECTIONS THROUGH THE DEVELOPMENT OF AN UNDERSTANDING OF THE EARLY LIFE HISTORY POPULATION DYNAMICS OF SEA LICE ASSOCIATED WITH ATLANTIC SALMON AQUACULTURE SITES IN THE BAY OF FUNDY

A better understanding of the early life history infection dynamics of sea lice on farms is essential to implementing more effective management measures aimed at disrupting the reproductive cycle of sea lice. Whereas most previous management approaches have considered sea lice larval stages as passive particles to be advected away from farms with oceanographic currents, the data confirming this assumption are scarce. Field sampling has shown that larvae are almost exclusively found in close proximity to active salmon farms, and lab studies have shown that sea lice populations can successfully reproduce in tanks with high flushing rates. These observations suggest that larval stages are far from being passive particles, and that they have certain early life history characteristics that allow them to quickly multiply on salmon farms. The rapid proliferation of sea lice to epidemic levels results in significant impacts to the aquaculture industry, and can have unintended consequences on wild populations, including other fish and invertebrates. This project examines the relative risk of amplification and transmission of infectious outbreaks of sea lice within the salmon aquaculture industry in the Bay of Fundy. The research will provide insight into infection dynamics within a farm as well as an assessment of the risk of transmission of sea lice away from the farm.

JUL. 2014–MAR. 2017

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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TRANSPORT AND DISPERSAL OF DISCHARGED SEA LICE CHEMICAL THERAPEUTANTS IN SOUTHWEST NEW BRUNSWICK

The use of therapeutant chemicals for treating sea lice outbreaks at salmon farms in southwest New Brunswick has raised concerns about the impacts of such chemicals on the marine environment, and in particular, on non-target organisms. This study used a combination of dye and pesticide concentration measurements, time lapse photography, moored current meters, free floating drifters, GPS tracing and tracking of dye patch edges, *in situ* fluorometry, computer hydrodynamic, and particle tracking modelling to study and quantify the mixing, flushing, transport, and dispersal of dye and pesticide from net pen tarp and skirt as well as well boat bath treatments. Two pesticides, primarily hydrogen peroxide (Paramove®), azamethiphos (Salmosan®) were used, although, some work was also conducted with deltamethrin (Alphamax®). The study was first conducted in southwest New Brunswick and was later extended to include offshore areas and Grand Manan; this work focused on the effect of dye-therapeutant plumes on zooplankton communities. Site-specific differences in physical environmental parameters influenced the depth, the direction and extent of the pesticide transport. Well boat bath treatments were found to pose the least environmental risk since the quantity of pesticide used was smaller than needed for tarp and skirt treatments, and the rate of dilution associated with well boat based effluent discharges was greater than for tarp or skirt discharges. The results of these studies provide additional science-based data to inform environmental risk assessments and the development of an integrated pest management strategy.

Dye released at an aquaculture site in New Brunswick as part of a field trial to study the transport and dispersal of sea lice chemical therapeutants. Photo: Fred Page (DFO)

APR. 2010–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Fred Page (DFO)

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THE EFFECTS OF SINGLE AND REPEAT *LEPEOPHTHEIRUS SALMONIS* (SEA LICE) INFECTIONS ON THE HEALTH OF JUVENILE PACIFIC SALMON

There is evidence that different species of Pacific salmon differ in their susceptibility to infections with the sea louse, *Lepeophtheirus salmonis*, under laboratory conditions. For example, Pink and Coho Salmon have been shown to be less susceptible to sea lice infections than Chinook or Chum Salmon. This multi-year project examined the susceptibility and lethal infection level of juvenile Sockeye, Coho, and Chum Salmon to *L. salmonis*. In addition, the effects of previous exposure to *L. salmonis* on susceptibility to infection and the physiological and immunological responses were determined for these species. The project provides managers with tools to help evaluate risks to juvenile salmon, particularly Sockeye Salmon, associated with sea lice infections. The results may be useful in establishing criteria for netpen salmon aquaculture related to siting and site-related thresholds such as production limits and stocking densities.

APR. 2010–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Simon Jones, Stewart Johnson (DFO)

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BIOASSAYS WITH FARM COLLECTED SEA LICE FROM ALL NEW BRUNSWICK AQUACULTURE BAY MANAGEMENT AREAS USING ALL APPROVED SEA LICE TREATMENT OPTIONS

New Brunswick Department of Agriculture, Aquaculture and Fisheries (NBDAAF) is expected to conduct bioassays to determine the efficacy of all approved sea lice treatment options as outlined under both government regulations and the NB Integrated Pest Management Plan. Completing bioassays is essential to confirm efficacy or resistance of the sea lice population within distinct geographic areas (e.g., Aquaculture Bay Management Areas) to a specific treatment compound and concentration (e.g., Salmosan®). Conversely, bioassays allow confirmation that resistance to a product has been reversed or lost (e.g., SLICE®) within a distinct geographical area. The project will result in completion of bioassays using two approved treatment options on sea lice collected from operating sea cage sites within all five of the NB Aquaculture Bay Management Areas (ABMA). The bioassays will be completed following summer and fall sea lice collections to allow seasonal comparison of the efficacy of each treatment option within NB ABMAs. This process will initiate an essential "early warning diagnostic tool" to alert government, Atlantic Salmon producers and pharmaceutical companies of an impending resistance to a registered sea lice treatment option while maintaining New Brunswick capacity to complete sea lice and related bioassay studies.

Early detection of an impending resistance of sea lice to a registered treatment option is essential for implementation of an effective Integrated Pest Management Plan. Timely results will give industry an opportunity to switch to alternate treatments and further advise for the need for registration of additional products from the pharmaceutical therapeutant pipeline.

JUL. 2014–DEC. 2014

FUNDED BY: NB Department of Agriculture, Aquaculture and Fisheries **CO-FUNDED BY:** Huntsman Marine Science Centre (HMSC)

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PROJECT TEAM: Mike Beattie (NBDAAF)

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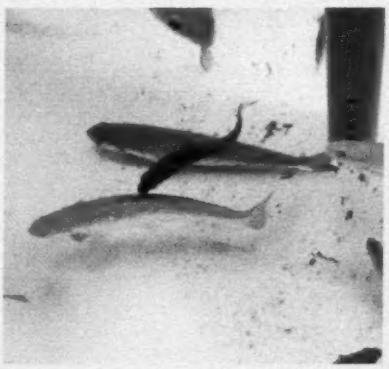
THE POTENTIAL OF USING NEWFOUNDLAND STOCK CUNNERS TO CONTROL SEA LICE (*LEPEOPHTHEIRUS SALMONIS*) ON INFECTED ATLANTIC SALMON SMOLTS: TANK TRIALS

Prolonged use of chemical therapeutants (e.g., SLICE®) to control sea lice (*Lepeophtheirus salmonis*) infestations on farmed Atlantic Salmon has the potential to lead to the development of local sea lice populations that are resistance to the therapeutant. The use of cleaner fish (e.g., Wrasse sp.) to remove sea lice from Atlantic Salmon in cages has been utilized in Europe with some success. The seriousness of developing chemical resistance in Canada, along with the desire of the industry and regulators to move towards a more sustainable integrated pest management approach, has prompted interest in the potential utilization of local fish species as cleaner fish to supplement and reduce reliance on the use of chemical therapeutants. This project tested the success and efficiency of cunners at feeding on sea lice by stocking cunners in tanks with sea lice-carrying salmon smolts. There was a significant decline in the numbers of sea lice in tanks containing cunners versus a control tank containing infected salmon without cunners. Video



Stop frame photo of a cunner picking sea lice from a salmon. Photo: Lynn Lush (DFO)

work confirmed that cunners did actively pick sea lice off of the salmon. Cunners showed an increase in activity with cohabitation time with salmon. Salmon groups with cunners showed an increased level of blood cortisol (an indicator of physiological stress). The group without cunners showed a decrease (non-significant) in cortisol.

This research has shown that in a tank system, Newfoundland cunners will effectively clean sea lice from Atlantic Salmon smolts. The recognized development of sea lice resistance to chemotherapeutics on the East Coast is a serious concern to the aquaculture industry, and the potential utilization of cleaner fish in this region offers new avenues toward sustainability for the industry.

APR. 2013–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon Inc.

PROJECT LEADS: Dounia Hamoutene, Harry Murray (DFO)

COLLABORATORS: Cold Ocean Salmon Inc.

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DISEASE GENOMICS FOR SALMON LOUSE RESISTANCE IN A COMMERCIAL STRAIN OF ATLANTIC SALMON

The development of Atlantic Salmon that are genetically more resistance to sea lice would economically benefit Canada's aquacultural industry, as well as reducing the use of chemotheraputants. The salmon louse, *Lepeophtheirus salmonis*, is an ectoparasite that negatively impacts the Canadian aquacultural industry, especially Atlantic Salmon (*Salmo salar*) in New Brunswick. We are looking at the possibility of a genetic improvement program in the Saint John aquaculture strain of Atlantic Salmon for salmon lice resistance using marker assisted selection, as sea lice resistance is a heritable trait.

By subjecting recent smolts to this species of sea lice, we establish the level of resistance each fish has by counting the number of sea lice attached. Then using genotypic data we look for DNA markers called single nucleotide polymorphisms (SNPs) associated with this resistance. Our current methodology expands from our past studies in that we are now genotyping 50,000 SNPs for fish challenged to sea lice, and 220,000 SNPs for potential broodstock, of which 126,000 work well for the North American subspecies. As the parents of the challenged fish are also genotyped, we will be able to input to 126,000 SNPs, allowing us to cover more of the genome compared to our past studies. SNPs associated with a high level of resistance will be implemented into Atlantic Salmon breeding programs, along with SNPs associated with other economically important traits.

MSc. student, Melissa Holborn, taking fin clips for genotyping. Photo: Derek Lapp

APR. 2014–MAR. 2017

FUNDED BY: Genome Canada **CO-FUNDED BY:** Cooke Aquaculture Inc; NRC – IRAP; ACOA

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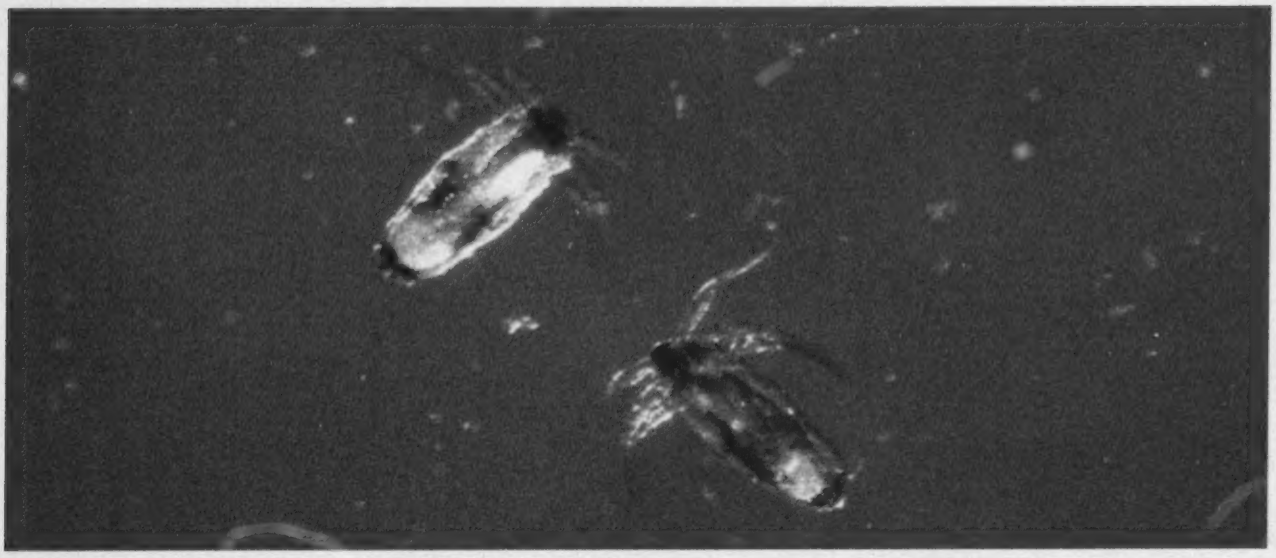
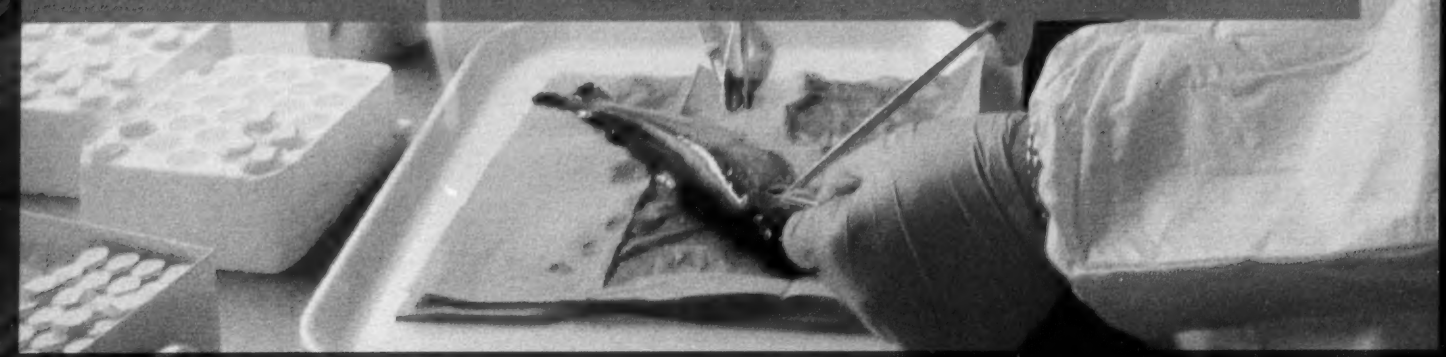


Sea lice larvae (*Lepeophtheirus salmonis*) in the nauplii stage. Photo: Emily Nelson (DFO)

FISH HEALTH

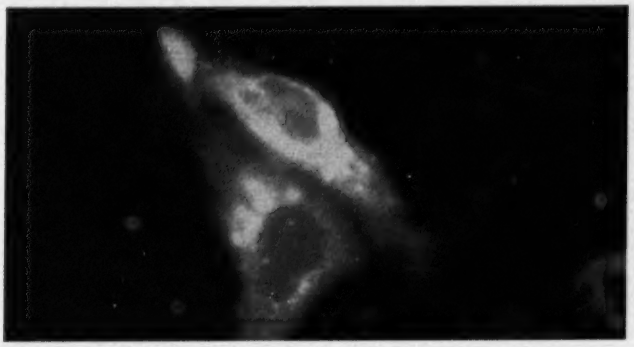
- PATHOGEN SUSCEPTIBILITY OF SOCKEYE SALMON - PHASE 1: INFECTIOUS SALMON ANEMIA (ISAV) AND ALPHAVIRUS (SPDV)
- STUDY OF GENOMIC DIVERSITY IN *AEROMONAS SALMONICIDA*, THE ETIOLOGICAL AGENT THAT CAUSES FURUNCULOSIS, TO ESTABLISH ITS RESISTOME, EPIDEMIOLOGICAL MARKERS AND POTENTIAL TREATMENTS
- ESTIMATING THE POTENTIAL FOR WATERBORNE TRANSMISSION OF INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS (IHNV) BETWEEN SALMON FARMS AND WILD SOCKEYE IN THE DISCOVERY ISLANDS, BRITISH COLUMBIA
- DETERMINATION OF *CRYPTOSPORIDIUM* SPP. OOCYST LEVELS IN THE HILLSBOROUGH RIVER, PRINCE EDWARD ISLAND
- INFECTIOUS SALMON ANEMIA VIRUS SUSCEPTIBILITY AND HEALTH STATUS OF WILD VERSUS CULTURED ATLANTIC SALMON: A COMPARATIVE STUDY
- INVESTIGATING PROBIOTIC BACTERIA AND THEIR BACTERIOCINS AS PART OF A DISEASE MANAGEMENT STRATEGY IN SALMON AQUACULTURE
- DOES CHALLENGE WITH THE BRITISH COLUMBIA STRAIN OF PISCINE REOVIRUS AFFECT ATLANTIC OR SOCKEYE SALMON?
- COMPARISON OF FIELD ISOLATES OF *MORITELLA VISCOSA*: CHARACTERIZATION AND *IN VIVO* CHALLENGE MODEL DEVELOPMENT TO ADDRESS WINTER ULCER MITIGATION IN CANADA
- LOW PATHOGENIC INFECTIOUS SALMON ANEMIA VIRUS (ISAV) *IN VIVO*: A COMPARATIVE GENOMIC STUDY
- DESCRIPTION OF OCEANOGRAPHIC CONDITIONS WITHIN HERMITAGE BAY, NEWFOUNDLAND, AT SITES WITH AND WITHOUT THE OCCURRENCE OF ISA OUTBREAK
- DEVELOPMENT OF A NOVEL RNA-BASED TREATMENT AGAINST THE INFECTIOUS SALMON ANEMIA VIRUS (ISAV)
- FIELD VALIDATION OF DIETARY MEDICATION TO REDUCE THE SEVERITY OF *KUDOA THYRSITES* IN FARMED ATLANTIC SALMON
- IDENTIFICATION AND TREATMENT OF GYRODACTYLID INFECTIONS IN CULTURED WOLF EELS (*ANARRHICHTHYS OCELLATUS*)
- DOES INFECTION WITH PISCINE REOVIRUS (PRV) EFFECT HOW SALMON RESPOND TO CHALLENGE WITH AND VACCINATION AGAINST INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS (IHNV)?
- THE EFFECTS OF PRIOR EXPOSURE AND BODY SIZE ON THE INTENSITY OF *KUDOA THYRSITES* INFECTIONS IN ATLANTIC SALMON
- FISH PEST AND PATHOGEN CULTURED TO WILD TRANSFER POTENTIAL: STOCKING DENSITY EFFECT
- IDENTIFICATION OF VECTORS OF MSX TO SUPPORT I&T DECISIONS RELATED TO INTER-PROVINCIAL MOVEMENTS OF MUSSELS: IS MUSSEL INTRA-VALVULAR LIQUID A VECTOR FOR MSX TRANSMISSION?
- SALMON PANCREAS DISEASE (ALPHAVIRUS) CHALLENGE AND VALIDATION OF RT-qPCR AND VIROLOGY TESTING
- VALIDATION OF A REVERSE TRANSCRIPTION QUANTITATIVE POLYMERASE CHAIN REACTION (RT-qPCR) ASSAY TO DETECT INFECTIOUS PANCREATIC NECROSIS VIRUS (IPNV)
- DESIGN OF PROTOCOLS FOR THE OZONE DISINFECTION OF FISH EGGS FOR ERADICATION OF VERTICALLY TRANSMITTED DISEASES
- REFINEMENT OF AN INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS DISPERSION MODEL FOR THE DISCOVERY ISLANDS AREA AND AN EXTENSION TO WEST COAST OF VANCOUVER ISLAND
- RAPID DETECTION OF REPLICATING INFECTIOUS SALMON ANEMIA VIRUS - PHASE 2
- REFERENCE GENE MEASUREMENT AS A PROXY FOR VIRUS DEGRADATION
- SUB-CLINICAL EFFECTS AND METABOLISM OF THE FEED-BORNE *FUSARIUM* MYCOTOXIN DEOXYNIVALENOL (DON) IN RAINBOW TROUT
- DETERMINING THE LONG TERM VIABILITY OF WHITE SPOT DISEASE IN LOBSTER EXPERIMENTALLY INFECTED THROUGH DIET
- CONFIRMATION OF THE VIABILITY AND INFECTIVITY OF WSSV-INFECTED SHRIMP USED IN A FEED CHALLENGE TRIAL INVOLVING AMERICAN LOBSTER
- THE USE OF RNALATER FOR THE INACTIVATION OF THE INFECTIOUS SALMON ANEMIA VIRUS
- DEVELOPMENT AND DIAGNOSTIC VALIDATION OF A qPCR ASSAY TO DETECT *MIKROCYTOS MACKINI*
- MEGALOCYTIVIRUS/RED SEA BREAM IRIDOVIRUS QUANTITATIVE PCR ASSAY DEVELOPMENT: PHASE 1 - MEGALOCYTIVIRUS ISOLATE COLLECTION, VIRUS AMPLIFICATION, AND STAKEHOLDER CONSULTATION
- ESTABLISH AN EXPERIMENTAL HOST-PATHOGEN MODEL INVOLVING RED SEA BREAM IRIDOVIRAL DISEASE AGENT (RSIV) IN FINFISH AND PRODUCE RSIV-INFECTED TISSUE
- REVERSE TRANSCRIPTION QUANTITATIVE POLYMERASE CHAIN REACTION (RT-qPCR) DIAGNOSTIC ASSAY FOR DETECTION OF SPRING VIREMIA OF CARP VIRUS (SVCV) - DIAGNOSTIC VALIDATION PHASE IIA (SAMPLE GENERATION AND DISTRIBUTION)
- THE EPIDEMIOLOGY OF WINTER ULCER DISEASE IN FARMED ATLANTIC SALMON IN CANADA
- RAPID DETECTION OF REPLICATING INFECTIOUS SALMON ANEMIA VIRUS
- DETERMINE IF THE PRESENCE OF HPR0 GENOMIC MATERIAL (DETECTED USING RT-qPCR IS ASSOCIATED WITH THE CONCURRENT PHYSICAL PRESENCE OF VIRAL MATERIAL (I.E., DISTINCT VIRIONS OR PARTIAL VIRUS ASSEMBLY, EVIDENCE OF VIRUS REPLICATION AND LOCALIZED TISSUES OR CELL SPECIFIC PATHOLOGICAL CHANGES) THAT IS CONSISTENT WITH INFECTIOUS SALMON ANAEMIA VIRUS (ISAV)
- DEVELOPMENT OF ARTIFICIAL REFERENCE MATERIAL FOR ASSESSING IHNV AND VHSV RT-qPCR ASSAYS



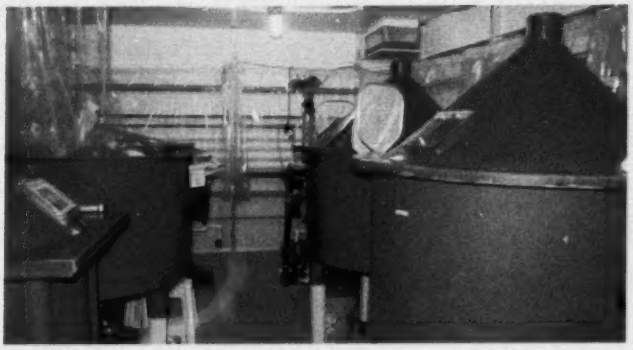
PATHOGEN SUSCEPTIBILITY OF SOCKEYE SALMON – PHASE 1: INFECTIOUS SALMON ANEMIA (ISAV) AND ALPHAVIRUS (SPDV)

Sockeye Salmon (*Oncorhynchus nerka*) is the third most common Pacific salmon species, after Pink and Chum Salmon. The Fraser River salmon run has experienced declines in productivity since the 1990s. The reasons for this decline remain speculative. The Commission of Inquiry into the Decline of Sockeye Salmon in the Fraser River was launched as a consequence. One recommendation of the report is that "The DFO should undertake or commission research into the health of Fraser River Sockeye Salmon, including: the hypothesis that diseases are transmitted from farmed salmon to wild Sockeye".

The CFIA-led, BC surveillance was launched in 2012. Thousands of samples were tested for ISAV and none was found. Although the testing meets the statistical requirements to eventually declare disease freedom, it does not look at the susceptibility of Pacific salmon species to the pathogens targeted. The risk of introduction is minimal but the consequences of an introduction or of an outbreak in a farm are not predictable without this data. We propose to examine disease resistance or susceptibility of Sockeye to various pathogens known to affect Atlantic Salmon, e.g., ISAV and SPDV (or Salmon Alphavirus). With the expertise in DFO, along with high level biocontainment facilities, this type of disease research can proceed and will generate essential knowledge for better management practices.



Immunostained ISAV infected cells. Photo: Mélanie Roy



Bio-containment facility Photo: Nellie Gagné

APR. 2014–MAR. 2018

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP)

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STUDY OF GENOMIC DIVERSITY IN *AEROMONAS SALMONICIDA*, THE ETIOLOGICAL AGENT THAT CAUSES FURUNCULOSIS, TO ESTABLISH ITS RESISTOME, EPIDEMIOLOGICAL MARKERS AND POTENTIAL TREATMENTS

Increased knowledge of the pathogen will aid Canadian aquaculture productivity while enabling growers to: (1) make appropriate use of antibiotics during treatment; (2) better track the pathogen's location; and (3) suggest alternatives to antibiotics as treatment.

The *A. salmonicida* bacterium is the infectious agent that causes furunculosis in salmonids (salmon, trout, Arctic Charr, etc.). Controlling this disease, which is very harmful to the aquaculture industry, can prove to be quite demanding and fruitless, mainly because of the logistic constraints of the vaccination and the very frequent resistance of *A. salmonicida* to several antibiotics. We are therefore studying the genomic diversity of *A. salmonicida* to better understand its virulence and its antibiotic resistome. Through familiarization with this diversity, tools and alternative treatments for preventing or curing furunculosis can be created. In concrete terms, we are developing a kit for quickly diagnosing antibiotic resistance. We are also studying the action of mobile DNA elements in the evolution, host adaptation, and geographic distribution of *A. salmonicida*, and their potential activation by various treatments, including the effect of certain essential oils with a view to developing a treatment. It is also our intent to verify the potential of bacteriophages (viruses that infect bacteria) as a cure for furunculosis. Furunculosis is a recurrent disease that is hard to control and, as such, all of these approaches must be considered in order to control it.

NOV. 2012–MAR. 2019

FUNDED BY: Natural Sciences and Engineering Research Council of Canada (NSERC) **CO-FUNDED BY:** Ressources Aquatiques Québec (RAQ), MAPAQ (Innovamer program); Société de recherche et de développement en aquaculture continentale (SORDAC)

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ESTIMATING THE POTENTIAL FOR WATERBORNE TRANSMISSION OF INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS (IHNV) BETWEEN SALMON FARMS AND WILD SOCKEYE IN THE DISCOVERY ISLANDS, BRITISH COLUMBIA

Results from this study will provide further tools to manage infectious hematopoietic necrosis virus, and allow DFO to ensure the protection of farmed and wild fish health by determining optimal locations for aquaculture sites.

In British Columbia, infectious hematopoietic necrosis virus is responsible for major economic losses in Atlantic Salmon aquaculture operations. Due to the significance of this pathogen, it is important to understand the risk of, and factors affecting, viral dispersion from infected sites. To this end, this study is developing a viral dispersion model for the Discovery Islands, an area home to multiple net-pen salmon farms. Accurate geo-spatial predictions of risk for IHNV transmission are simulated through the coupling of IHNV transmission parameter estimates as reported (PLoS ONE 8(12):e82296) with a recently developed hydrodynamic ocean circulation model for the Discovery Islands (Atmosphere-Ocean 50(3):301-306). Additionally risk estimates are not only quantified for disease transmission potential between farms, but also between farmed Atlantic and wild Sockeye Salmon. Utilizing empirical data obtained through controlled laboratory exposure studies, the susceptibility of saltwater phase Sockeye Salmon to IHN disease is determined. Ultimately, temporally- and spatially-evolving viral concentration maps are combined with the lab-determined minimum infectious dosages to estimate the infection connectivity among farms and risk of virus spread to wild fish.

JUN. 2013–APR. 2015

FUNDED BY: DFO-Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Marine Harvest Canada; Grieg Seafood; Cermaq

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Discovery Islands aerial photo. Photo: Kyle Garver (DFO)

DETERMINATION OF *CRYPTOSPORIDIUM* SPP. OOCYST LEVELS IN THE HILLSBOROUGH RIVER, PRINCE EDWARD ISLAND

Contamination of oysters occurs predominantly in coastal or estuarine environments with wastewater sewage discharge and agricultural run-off from farms. *Cryptosporidium* spp. is a zoonotic protozoan parasite that has been detected in many shellfish species in both fecal-contaminated and clean oyster growing areas across the globe. Despite this fact, no data are available on oocyst concentrations in harvest-zone waters or in oysters harvested in Prince Edward Island. An assessment of the levels of this parasite in areas where the health authorities permit oyster harvesting is an important public health concern.

The primary objective of this project is to determine the concentrations of *Cryptosporidium* oocysts in water from three different shellfish harvest zones (prohibited, restricted, and approved) during the spring season after a rainfall event (which would indicate a higher risk of contamination). Some oyster sampling will be done concurrently to compare the concentrations of the parasite with findings from unpublished data by Willis *et al.* (2012) and to provide information about the accumulation of oocysts in oysters in the field.

We hypothesize that: (1) The number of oocysts will be greatest in the prohibited zones, followed by restricted zones, with zero prevalence in approved zones, and; (2) the level of oocysts in the water will be increased by rainfall events.

Our results will be linked to a risk assessment model for the probability of human illness due to consumption of contaminated oysters with *Cryptosporidium* spp. in PEI.

MAY 2014–APR. 2015

FUNDED BY: Canada Excellence Research Chair (CERC) – Aquatic Epidemiology, UPEI

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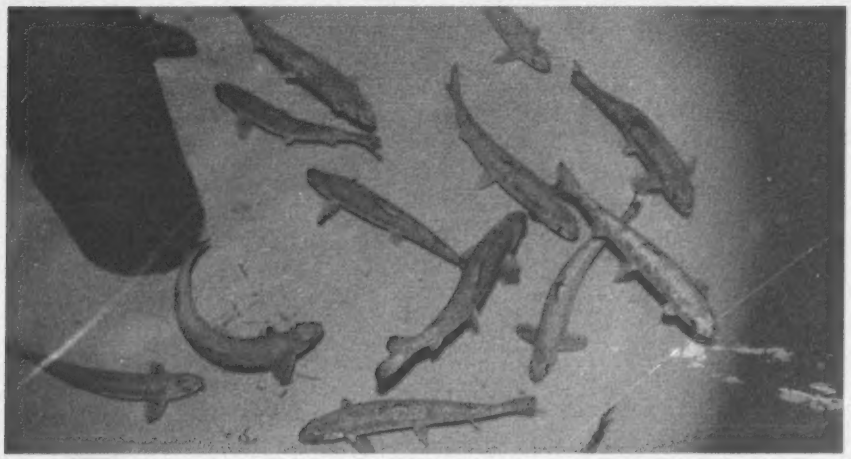
INFECTIOUS SALMON ANEMIA VIRUS SUSCEPTIBILITY AND HEALTH STATUS OF WILD VERSUS CULTURED ATLANTIC SALMON: A COMPARATIVE STUDY



Atlantic Salmon in quarantine (tanks). Photo: Nellie Gagné (DFO)

There are serious concerns about the status of wild Atlantic Salmon in Atlantic Canada, and many populations are designated threatened or endangered by COSEWIC. The potential interactions between cultured and wild salmon in areas where they coexist are a primary concern. The health status and disease resistance of wild Atlantic Salmon (wAS) is unknown, whereas information for cultured Atlantic Salmon (cAS) is abundant. For example, while Infectious Salmon Anemia Virus (ISAV) remains a recurrent problem for the salmon aquaculture industry in Atlantic Canada, with outbreaks detected in Nova Scotia (NS) and Newfoundland (NL) since 2012, knowledge regarding the prevalence of this virus in wild populations as well as the potential transmission between wild and cultured stocks is lacking.

This project proposes to use *in vivo* disease challenges and next generation sequencing (NGS) technologies to compare the susceptibility of wild Atlantic Salmon stocks (Saint John River, Inner Bay of Fundy, Miramichi, and Margaree river stocks) and cultured stocks (Saint John River origin) to ISAV. The use of NGS (RNASeq) will enable us to look at genetic differences and measure immune responses and general health status, which could potentially explain differences in susceptibility (if observed). Additionally, we will examine the evolution rate of ISAV by looking at full ISAV sequences in tissues thoughout the course of the *in vivo* challenges.

APR. 2014–MAR. 2017

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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INVESTIGATING PROBIOTIC BACTERIA AND THEIR BACTERIOCINS AS PART OF A DISEASE MANAGEMENT STRATEGY IN SALMON AQUACULTURE

This research will offer the first comprehensive assessment of the antibiotic properties of known and unknown bacteriocins and, as such, constitutes an investigation into a novel category of drug treatment. The results of this research will help inform disease management strategies to minimize the impact of pathogens and ultimately improve fish health.

The susceptibility of farmed salmon to bacterial disease and sea lice (*Lepeophtheirus salmonis* and *Caligus* species) is a health management issue for the aquaculture industry. Currently, antibiotics and antiparasitics are used to treat bacteria and sea lice, respectively, however, there are concerns regarding the effectiveness and long term sustainability of these methods. This research project will evaluate the potential for probiotic bacteria (microorganisms associated with beneficial effects to humans and animals) and bacteriocins (antimicrobial, naturally occurring compounds produced by certain bacteria) to aid in the reduction of antibiotics currently used to treat bacterial diseases in salmon. Another point of focus will be on the potential of *Bacillus* and *Paenibacillus* bacterial species to aid in reducing the use of chemical therapeutants, such as emamectin benzoate (SLICE®), as a treatment of sea lice infections in salmon.

APR. 2014–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Cermaq Canada; Marine Harvest Canada Inc.; National Strategic Research and Engineering Council (NSERC)

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COLLABORATORS: Cermaq Canada; Marine Harvest Canada Inc.

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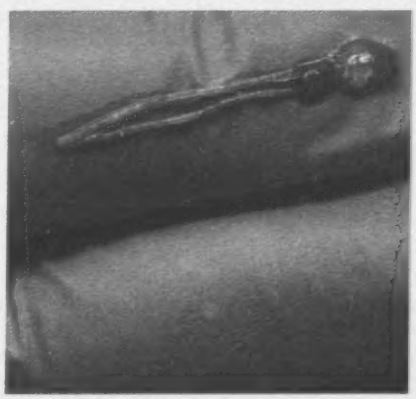
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm



Mature female sea louse (*Lepeophtheirus salmonis*) with egg strings. Photo: Emily Nelson (DFO)

DOES CHALLENGE WITH THE BRITISH COLUMBIA STRAIN OF PISCINE REOVIRUS AFFECT ATLANTIC OR SOCKEYE SALMON?

This study suggests PRV from the Pacific Coast of British Columbia is of low pathogenicity in Atlantic and Sockeye Salmon.

Piscine reovirus (PRV) was first discovered in Norwegian farmed Atlantic Salmon with the disease heart and skeletal muscle inflammation (HSMI). While fish with HSMI generally carry higher loads of PRV, clinically healthy fish in Norway also carry the virus. PRV is geographically widespread, occurring in the Atlantic, as well as in wild and farmed salmon in the Pacific Ocean where HSMI has not been reported. Consequently, the presence of PRV in asymptomatic fish raises questions concerning the exact relationship between PRV and HSMI. To evaluate the risk posed to native and cultured salmon residing in the Pacific, we utilized controlled laboratory exposures to determine virulence of PRV in Atlantic and Sockeye Salmon. Naïve Atlantic Salmon challenged by intraperitoneal injection of PRV positive tissue homogenate resulted in development of a sustained PRV infection; however, compared to control groups there were no significant differences in morbidity due to PRV exposure and no evidence of HSMI. We also demonstrated that PRV could spread to naïve Atlantic and Sockeye Salmon by waterborne transmission with nearly 100% of naive fish becoming positive after 4 weeks of exposure. Despite the development of persistent infections, no fish to date have showed any morbidity, gross signs of disease, or histological evidence of HSMI when compared to controls.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Marine Harvest Canada

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PROJECT TEAM: Kyle Garver (DFO); Diane Morrison (Marine Harvest Canada)

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

COMPARISON OF FIELD ISOLATES OF *MORITELLA VISCOSA*: CHARACTERIZATION AND *IN VIVO* CHALLENGE MODEL DEVELOPMENT TO ADDRESS WINTER ULCER MITIGATION IN CANADA

The knowledge obtained through this research will be useful in the development of future vaccines for *Moritella viscosa*, which would provide a non-antibiotic, proactive strategy to address winter ulcer disease. Access to a licensed vaccine would increase the sustainability of salmonid aquaculture through improved animal welfare and reduced economic losses due to mortality, antibiotic use, and the downgrading of the product due to ulcer damage.

The bacteria *M. viscosa* is considered to be the main cause of winter ulcer disease, which primarily affects marine farmed salmonid fish during cold periods. Winter ulcer disease is becoming a high priority problem for Canadian producers, and while mortalities vary according to site, a large number of the remaining fish are also affected by the disease. To date, there is no vaccine licensed for winter ulcer disease in Canada, and the demand for access to vaccines is growing. Current vaccines are based on European disease strains, and in order for the vaccine to be licensed for use in Canada, its efficacy against Canadian strains must be examined.

This project aims to establish a live challenge model (in which the animal is given the bacteria to assess their response) relevant to *M. viscosa* outbreaks in Canada which can be used for future vaccine development studies. This will involve: (1) a series of *in vitro* (cell culture) studies to better understand how the bacteria grow in the presence of salmon cells and determine immune response differences between Canadian strains; and (2) selecting two sources of bacteria to be used to develop a disease challenge model using live Atlantic Salmon. The challenge model will help to determine a good candidate strain that will produce testable predictable results, a challenge exposure method, and a culture exposure temperature.

APR. 2014–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Cooke Aquaculture Inc., Novartis Animal Health Canada Inc.

PROJECT LEAD: Steven Leadbeater (DFO)

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LOW PATHOGENIC INFECTIOUS SALMON ANEMIA VIRUS (ISAV) *IN VIVO*: A COMPARATIVE GENOMIC STUDY

Since the initial identification of Infectious Salmon Anemia Virus (ISAV) in Norway in 1984, and in the Bay of Fundy in 1996, viral evolution and selective pressure, combined with improved detection have revealed an interesting and challenging ISAV portrait, that is, the presence of essentially avirulent strains such as the HPR0 variant, as well as highly virulent strains, such as HPR4 variants. Additionally there are many other strains identified which have varying degrees of virulence. The ISAV remains a looming threat to the salmon aquaculture industry, and ISAV continues to evolve. This study will contain an in-depth assessment of the etiology of ISAV to gain further understanding of the variable virulence and infection dynamics observed, *in vivo*, in salmon.

APR. 2011–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

DESCRIPTION OF OCEANOGRAPHIC CONDITIONS WITHIN HERMITAGE BAY, NEWFOUNDLAND, AT SITES WITH AND WITHOUT THE OCCURRENCE OF ISA OUTBREAK

Should there be a correlation between environmental parameters and the occurrence of Infectious Salmon Anemia (ISA) outbreaks, the results of this project will help identify other areas of the region when and where there is a potential risk of outbreak. This would provide the aquaculture industry with an anticipatory tool on how to mitigate the risk and improve the sustainability of salmon farming.

The first reported case of ISA disease was in a salmon farm in Hermitage Bay, Newfoundland (NL), in the summer of 2012 and a few more cases of ISA outbreaks have been reported in the same region since that time. The optimum temperature survival conditions of the virus, 5 to 15°C in seawater, coincide with farmed rearing conditions in the regions but stressors to farmed species may lead to increases in the infection rates.

This project aims to understand the variability of the oceanographic conditions in Hermitage Bay, NL, and assess the potential link between those conditions (temperature, salinity, and dissolved oxygen) and the occurrence of ISA outbreaks. In that bay, some sites have reported ISA outbreaks, although at different periods of the year, while others did not and it is suggested that the possible differences in the physical parameters surrounding these sites might have had an effect on the overall health conditions of the fish (i.e., stress) and allowed for an outbreak of the virus. This research project will address the physical properties of the water and analyze the conditions before and during ISA outbreak, in order to identify the environmental conditions associated with the outbreak and assess the possible correlation between the conditions and the outbreak.

APR. 2014–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon; Newfoundland Aquaculture Industry Alliance (NAIA)

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DEVELOPMENT OF A NOVEL RNA-BASED TREATMENT AGAINST THE INFECTIOUS SALMON ANEMIA VIRUS (ISAV)

This project has provided insight into the viral replication of Infectious Salmon Anemia Virus (ISAV) and provides support for the use of ribonucleic acid interference (RNAi) against marine viruses like ISAV. Further, this research has permitted the development of new tools that will greatly facilitate future work and help improve fish health management in the aquaculture industry.

ISAV, a significant viral pathogen, causes mass mortalities and represents a recurrent problem to the salmon aquaculture industry. Current vaccines for ISAV do not offer total protection for the entire lifespan of cultured salmon. Additionally, no post-vaccination treatments exist for infections during the later stages of salmon development. This study explored the development of a novel RNAi-based vaccine as a treatment against the ISA virus. It was found that viral replication may be 10–100 times lower within treated cells compared to untreated control cells. Unfortunately, it was also discovered that cultured cells grown in the laboratory over a long period of time develop a resistance to the virus, and this resistance makes it difficult to truly assess the efficacy of the treatment. Further studies will have to be done to address the age-related resistance in order to better assess the efficacy of RNAi-based vaccines.

APR. 2009–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

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FIELD VALIDATION OF DIETARY MEDICATION TO REDUCE THE SEVERITY OF *KUDOA THYRSITES* IN FARMED ATLANTIC SALMON

Farmed Atlantic Salmon are at risk of infection with *Kudoa thyrsites* throughout British Columbia (BC), leading to an elevated risk of reduced fillet quality. The cost to the BC farmed Atlantic Salmon industry was over $15 million in 2010, adding to the difficulty for the BC industry to remain competitive in the global salmon market. Early screening of farmed stock is now often used for *Kudoa* detection. Neither vaccines nor medicines are currently available for the prevention or treatment of the infection. This project evaluated the efficacy of dietary nicarbazin against *Kudoa* in Atlantic Salmon held in a production environment.

The results of this study confirmed that under production conditions, treatment of seawater-reared Atlantic Salmon with a medicated diet containing nicarbazin results in elevated muscle residues of dinitrocarbanilide (DNC). The study also confirmed observations made in laboratory studies that DNC declines rapidly in muscle following cessation of medication. An alternative treatment regime will be required to ensure that DNC residues are sufficiently high over a longer duration during the grow-out phase of salmon production to maximize efficacy against *Kudoa* in harvest fish.

APR. 2011–OCT. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Marine Harvest Canada

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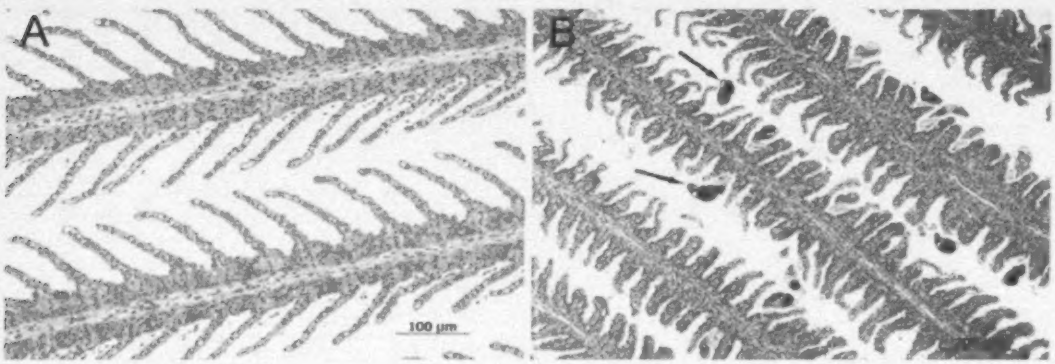
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

IDENTIFICATION AND TREATMENT OF GYRODACTYLID INFECTIONS IN CULTURED WOLF-EELS (*ANARRHICHTHYS OCELLATUS*)



Micrographs of wolf-eel (*Anarrhichthys ocellatus*) histological sections. A, normal gill; B, gill infected with *Gyrodactylus corti* (arrows) showing thickened lamellae, indicative of epithelial hyperplasia. Photo: Simon Jones (DFO)

Wolf-eels (*Anarrhichthys ocellatus*) are considered an appropriate new species for development in the Canadian aquaculture industry and recent research has looked at the potential to move this culture species from experimental to commercial production. During their studies, researchers identified a commonly occurring parasite (*Gyrodactylus* spp.) that was responsible for recurring disease outbreaks in captive-reared wolf-eels which could ultimately impede production. The objective of this project was to investigate *Gyrodactylus* outbreaks occurring in captive reared wolf-eels, identify the species responsible, and develop an efficacious treatment protocol.

The parasite infecting wolf-eels at the CAER facility in West Vancouver was confirmed as *Gyrodactylus corti*, originally described from captive wolf-eels in California. This research suggested that *G. corti* is a common parasite of wolf-eels and that increased intensities of infection occur in captivity. Infections cause an acute reaction in the gills, which contributes to elevated mortality. Infection with *G. corti* caused mortality as high as 83% among captive wolf-eels.

This research demonstrated that the most effective treatment against *G. corti* was formalin baths and, to a lesser extent, freshwater baths. However, both treatments only provide temporary or partial benefits as infections have been observed to recur. Careful management of newly captured wolf-eels, including quarantine and treatment is recommended. This research was needed to assess risk, develop treatment protocols, and to provide new information that will be essential for a successful wolf-eel aquaculture industry. Further research will need to explore additional regimes of formalin, freshwater, or combined treatments, in order to optimize results.

APR. 2012–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Kyuquot SEAfoods Ltd.; Vancouver Aquarium

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DOES INFECTION WITH PISCINE REOVIRUS (PRV) EFFECT HOW SALMON RESPOND TO CHALLENGE WITH AND VACCINATION AGAINST INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS (IHNV)?

Although co-infection of fish with multiple pathogens has long been recognized, the consequences of such infections have received little attention. This project will examine the consequences of viral co-infections in salmon, in particular, the relationship between the Piscine Reovirus (PRV) and Infectious Hematopoietic Necrosis Virus (IHNV) in Atlantic and Sockeye Salmon. Specifically, the study will address how hosts, infected with viruses of no or low pathogenicity effect, will respond to vaccination against and to challenge with other viruses. Challenge trials will be used to examine IHN disease progression in naïve and IHNV vaccinated non-PRV (control) and PRV-infected Atlantic Salmon. An IHNV challenge trial will also be conducted with non-PRV (control) and PRV-infected Sockeye Salmon that are naïve with respect to IHNV. These challenge trials will be used to determine if there are differences between groups in morbidity associated with IHNV challenge, and to generate biological samples for gene and microRNA expression studies. Transcriptional responses will be quantified using a combination of RNA-seq, also called "Whole Transcriptome Shotgun Sequencing", and Real Time Quantitative PCR. This research will help to determine what, if any, additional risk is posed to wild and/or farmed fish due to changes in their ability to respond to IHNV vaccination and/or challenge due to the presence of PRV.

SEP. 2014–DEC. 2016

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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THE EFFECTS OF PRIOR EXPOSURE AND BODY SIZE ON THE INTENSITY OF *KUDOA THYRSITES* INFECTIONS IN ATLANTIC SALMON

The knowledge gained through this research project will lead to a greater understanding of disease transmission and wild-farmed interactions. Additionally, this information will allow for better finfish cage siting and decision making and the development of tools to help further manage this disease.

The parasite, *Kudoa thyrsites*, is the cause of soft-flesh syndrome in post-harvest Atlantic Salmon farmed in British Columbia. Infected fish exhibit no clinical signs of disease, but the affected muscle rapidly deteriorates after processing. These infections can cause substantial economic hardship to the salmon aquaculture industry with some sites estimating a 10% loss of annual yield, resulting in losses of between $6–10 million. Currently, there are no vaccines or approved strategies for treatment (e.g., chemotherapeutic intervention) for *K. thyrsites*.

Earlier research revealed geographic variation in the prevalence and intensity of *K. thyrsites* in Atlantic Salmon reared at different seawater production sites. This research discovered that infections typically resolve between six and twelve months following laboratory exposure of fish to the parasite, and therefore, the occurrence of infections in harvested salmon after 18 months or more in seawater suggest multiple or ongoing exposures to the parasite during commercial net pen rearing.

This project will further investigate options for managing *K. thyrsites* infections. Firstly, it will test the efficacy of ultraviolet irradiation of seawater as a method to inactivate *K. thyrsites* in the laboratory and further study the influence of prior exposure to *K. thyrsites* on parasite development during subsequent exposure. The project will also assess the influence of fish size on the prevalence and severity of the infection.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Marine Harvest Canada; Mainstream Canada

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FISH PEST AND PATHOGEN CULTURED TO WILD TRANSFER POTENTIAL: STOCKING DENSITY EFFECT

Salmon farms infected with Infectious Salmon Anemia (ISAV) from wild stocks, can become an amplified source of ISAV which can subsequently be shed back to wild fish. Given the waterborne transfer and dispersal of ISAV, the resulting plumes or zones of ISAV may contribute to the transfer of the pathogen between farms, and to migrating wild salmon that intersect these plumes. Although the risk of pathogen transfer is of general concern to the industry and the general public alike, the DFO Maritimes Regional Regulators are particularly interested in the role of stocking density in potentially increasing pest and pathogen transfer from farms to endangered wild salmon in the Region. This study sets out to generate new information on ISAV shedding and infection rates of captive Atlantic Salmon. Laboratory studies will be conducted to estimate the shedding rate of ISAV from infected Atlantic Salmon as a function of fish stocking/handling density, the longevity of the infective capacity of waterborne ISAV, and the exposure profile for naive Atlantic Salmon to become infected with ISAV. The resulting information will be used to develop geographically specific physical-biological models for predicting the potential of waterborne spread of ISAV from farmed to wild salmon in the Maritimes Region of Atlantic Canada.

MAR. 2014–MAR. 2017

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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IDENTIFICATION OF VECTORS OF MSX TO SUPPORT I&T DECISIONS RELATED TO INTER-PROVINCIAL MOVEMENTS OF MUSSELS: IS MUSSEL INTRA-VALVULAR LIQUID A VECTOR FOR MSX TRANSMISSION?

With the increased participation of new partners, the number of requests for transfers of mussel seed and market product, both intra- and inter-provincially, is growing. The transfers of live mussels are regulated under the *Fisheries (General) Regulations*, Section 56, and are reviewed on a case by case basis by the Introductions and Transfer Committees (ITC) of the receiving Province. Multinucleated sphere X (MSX) is an infectious disease that causes heavy mortality in shellfish although it does not affect human health. To date, DFO analysis of mussels collected from heavily infected MSX positive areas of the Bras d'Or Lakes, and from MSX positive areas outside of the Lakes, has not detected MSX in the soft tissues/intra-valvular liquid. Nevertheless, concern remains with the unidentified secondary host(s) that may be transferred with the epifauna on the mussel lines. Applications to transfer "raw or unprocessed lines" or "primary processed lines" into MSX negative areas are increasing. In the absence of information, epifauna is considered potentially positive for MSX and mitigation recommended by the ITCs. However, identifying the secondary host may allow targeted mitigation (cleaning/time of year) and an accurate risk assessment of these proposed activities.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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SALMON PANCREAS DISEASE (ALPHAVIRUS) CHALLENGE AND VALIDATION OF RT-qPCR AND VIROLOGY TESTING

Alphavirus challenge at the Gulf Biocontainment Unit – Aquatic Animal Health Laboratory (GBU-AAHL)

Salmon pancreas disease virus (SPDV), the aetiological agent of pancreas disease (PD), is an alphavirus, belonging to the Togaviridae family. Diseased fish are often lethargic, with abnormal swimming behaviour and mortality can reach 50% in cages. Pancreas disease was first detected in farmed Atlantic Salmon, *Salmo salar* L., in Scotland in 1976. Since then it has also been described in Norway, France, and Spain.

Salmon aquaculture in Canada could be greatly affected by alphavirus if present. Diagnostic assays, including RT-qPCR, exist (Hodneland and Endresen, 2006) but have not been evaluated in full. Since fish origin greatly influences their susceptibility, an initial evaluation of the potential of PD to affect a Canadian strain of salmon (e.g., Saint John River) is warranted.

Project objectives completed in 2012 include: (1) the importation of live SPDV strains for the purpose of evaluating/developing a RT-qPCR assay; (2) initial growth in cell culture; (3) preparation of histological slides for training; and (4) determining the susceptibility of salmon to PD. A live challenge was performed at the The Gulf Biocontainment Unit – Aquatic Animal Health Laboratory (GBU-AAHL, a level three biocontainment facility). The project objectives for 2014/15 are: (1) to do individual viral culture assays for a subset of the tissues collected; (2) to compare viral culture and RT-qPCR, and obtain validation data (stage 1 and 2); and (3) to write a protocol and validation dossier.

The project provided relevant training for a virologist, histopathologist, and provides reference material for potential alphavirus cases and differential diagnostic. The information gathered during the live fish challenge, like tissue tropism and disease presentation, are essential for the eventual detection of SPDV in surveillance program.

APR. 2012–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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VALIDATION OF A REVERSE TRANSCRIPTION QUANTITATIVE POLYMERASE CHAIN REACTION (RT-qPCR) ASSAY TO DETECT INFECTIOUS PANCREATIC NECROSIS VIRUS (IPNV)

Infectious pancreatic necrosis (IPN) disease is a federally reportable aquatic animal disease in Canada. Although IPN virus (IPNV) is no longer an OIE listed pathogen, their recommended screening method for detection of the virus was virus isolation. Since the National Aquatic Animal Health Program (NAAHP) diagnostic labs use qPCR assays to screen samples, the need for a validated IPNV-specific qPCR assay was identified. The assays available in the published literature did not have the required performance characteristics so DFO pursued development of a new test method for detection of the virus.

DFO has developed and validated a new RT-qPCR test method for detection of IPNV. The assay is sensitive and is capable of recognizing IPNV isolates present in Canada as well as those that could be introduced into the country through international trade or domestic movement of aquatic animals. NAAHLS member labs are using the validated assay for IPNV testing of NAAHP samples.

DFO now has the capability to use RT-qPCR to detect the presence of IPNV in movements of fish within Canada and can respond to request from our trading partners for IPNV-free attestations.

APR. 2012–MAR. 2014

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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DESIGN OF PROTOCOLS FOR THE OZONE DISINFECTION OF FISH EGGS FOR ERADICATION OF VERTICALLY TRANSMITTED DISEASES

Pathogens can be introduced into a population by one of two methods, either through transmission from another infected individual (horizontal transmission) or by the passage of the pathogen from broodstock to the egg (vertical transmission). With vertical transmission, disinfection of eggs has become a critical step in aquatic husbandry, and is one of the most important methods of controlling transmissible diseases in an aquaculture facility. This project tested the effectiveness of ozonated water in preventing disease transmission while evaluating its effects on developing egg and larval performance.

Overall, salt-water ozone treatment showed no negative effects on cod eggs or larvae at levels tested (< 3.0 mg/L for 90 seconds) and has the potential to be a safe, effective disinfectant on Atlantic cod eggs. Similarly, ozone was also found to be an effective egg treatment against the fungus, *Saprolegnia diclina* for freshwater fish (Atlantic Salmon and Rainbow Trout), with negative growth of this fungus recorded in all treatments.

This project provided valuable insight into the use of ozone within hatcheries to directly disinfect fish eggs of three species of interest to aquaculture. This allows industry the opportunity to improve its overall environmental performance by limiting the traditional use of harsh chemicals to disinfect eggs. This investigation also provided an opportunity to scale up ozone trials from previous laboratory-scale models to a semi-commercial facility, thereby optimizing amounts of disinfectant to be used for larger quantity of eggs. While more research on the effectiveness of ozone on specific pathogens is necessary, the information gained through this project can help to greatly improve health management practices in controlling transmissible diseases within aquaculture facilities.

APR. 2010–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** Newfoundland Cod Broodstock Company

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REFINEMENT OF AN INFECTIOUS HEMATOPOIETIC NECROSIS VIRUS DISPERSION MODEL FOR THE DISCOVERY ISLANDS AREA AND AN EXTENSION TO WEST COAST OF VANCOUVER ISLAND

In British Columbia, infectious hematopoietic necrosis virus (IHNV) is the most economically important viral pathogen of salmonids. To begin to assess the risk of viral dispersal through waterborne transmission from an infected site, it is necessary to understand, not only the biological parameters associated with virus dispersion, but also the physical components of the environment in which the virus is being dispersed. This project aimed to refine the physical and biological measurements of the established viral dispersion model. Specifically, the risk of virus transmission from APEX vaccinated Atlantic Salmon was determined, as well as investigated the susceptibility of Sockeye Salmon to IHNV.

The vaccinated Atlantic Salmon were highly protected against the development of the lethal IHN disease such that out of 100 APEX vaccinated Atlantic Salmon only two fish succumbed to IHN disease. This protection was afforded regardless of whether the vaccinated fish were exposed to IHNV via intraperitoneal injection or waterborne immersion. In preliminary trials on Sockeye susceptibility to IHNV, no mortality was observed in either the mock challenge group or the two lowest virus exposure levels. Mortality was only observed at the two highest IHN virus exposure levels tested with cumulative mortality ranging from 8% to 36%.

Refuge Cove, Discovery Islands, BC. Photo: Darren Tuele (DFO)

Quantification of the IHNV transmission parameters obtained through this project will enable accurate geospatial predictions of risk for IHNV transmission from marine salmon sites. Understanding how the virus is dispersed among salmon farms will ultimately increase the sustainability of the aquaculture industry through optimization of fish health.

APR. 2011–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Grieg Seafoods; Mainstream Canada; Marine Harvest

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RAPID DETECTION OF REPLICATING INFECTIOUS SALMON ANEMIA VIRUS – PHASE 2

Modern diagnostic laboratories call upon a limited number of assays for the detection of pathogens. These assays are most often validated, which means that their behaviour in most situations is well documented and understood. For example, validated assays have defined limits of specificity and sensitivity. The work involved in validating an assay is quite significant, and in some sense, is never ending. Indeed, an important part of the validation process is the re-assessment and, if possible, improvement of the assay.

The detection of the Infectious Salmon Anemia Virus (ISAV) in diagnostic labs is currently achieved by two main methods based on either RT-qPCR amplification or by the observation of cytopathic effect (CPE) in cell cultures. Each of these methods has both advantages and drawbacks.

This research combines the strongest aspects of both these techniques, and adds new tweaks to the detection process, in an effort to modernize and improve upon our validated assays. Four distinct methods will be evaluated to measure the ease and rapidity they offer for the detection of replicating virus: (1) secondary RT-qPCR; (2) Electric Cell-substrate Impedance Sensing (ECIS); (3) co-centrifugation of virus and cell lines; and (4) the use of chemical aids for viral entry, exit, and replication.

This represents an improvement of one of the most utilized assays within the National Aquatic Animal Health Program (NAAHP). Further, the automation of some processes via ECIS and the detection of replicating HPR0 (a strain of ISAV) represent significant assets to the NAAHP pathogen detection methodologies.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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REFERENCE GENE MEASUREMENT AS A PROXY FOR VIRUS DEGRADATION

The National Aquatic Animal Health Program (NAAHP) recognized a need for a project that would provide a way to measure if a sample of viruses has decomposed too far for a reliable analysis.

Our approach was to get an index of viral decomposition by measuring the level of degradation in host species tissue. We evaluated the degradation of the host tissue and of the virus in the infected host tissue in parallel using RT-qPCR. Infected tissues were kept in various conditions. We were able to determine that the degradation of the RNAas indicated by the ref gene is also an indication of the degradation of ISAV in tissues. The choice of reference gene assay is important to get a good indication of virus degradation.

We now have the critical information needed to allow sound decision making if samples have been stuck in transit or if samples from external laboratories require testing by the Canadian Food Inspection Agency (CFIA) and there is doubt as to their condition.

APR. 2013–MAR. 2014

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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SUB-CLINICAL EFFECTS AND METABOLISM OF THE FEED-BORNE *FUSARIUM* MYCOTOXIN DEOXYNIVALENOL (DON) IN RAINBOW TROUT

Elucidation of the histopathological effects and an improved understanding of detoxification processes will provide information necessary for the potential development of more effective strategies to minimize the negative impacts of deoxynivalenol (DON) on sensitive aquaculture species. Furthermore, these studies provide a robust framework for aquaculture feed manufacturers to establish regulatory guidelines.

Contamination of fish feeds with mycotoxins is an issue of concern due to the increased use of economical plant proteins. Highly repeatable findings from several growth trials have confirmed that Rainbow Trout are extremely sensitive to the ubiquitous *Fusarium* mycotoxin, deoxynivalenol. Accordingly, a series of studies were conducted to investigate the basis of this sensitivity and to determine the efficacy of potential mitigation strategies. No distinct histopathological lesions were associated with feeding Rainbow Trout practically-formulated diets containing purified or naturally occurring DON. Increases in the number of dead cells and decreases in the number of mitotic figures in the pyloric caeca were observed. Similarly, some changes in the number of mitotic figures in the liver and in the degree of hepatic vacuolation were noted. A commercial feed additive was not efficacious in preventing negative effects of DON on growth, carcass composition, and nutrient utilization of Rainbow Trout. Comparatively, Nile Tilapia were not adversely affected by low dietary levels of DON. Increased digestible starch content does not appear to be an effective nutritional stragtegy for reducing the effects of DON on Rainbow Trout. Furthermore, species-specific sensitivity does not appear to be related to differences in hepatic UDP-glucuronosyltransferase activity.

SEP. 2010–NOV. 2014

FUNDED BY: Biomin (B.R.A.I.N. program)

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DETERMINING THE LONG TERM VIABILITY OF WHITE SPOT DISEASE IN LOBSTER EXPERIMENTALLY INFECTED THROUGH DIET

White Spot Disease (WSD) is a reportable disease of trade importance to the National Aquatic Animal Health Program (NAAHP) and the World Organisation for Animal Health (OIE). Knowledge of WSD's oral infectivity in fed lobsters at set temperatures was required to support current trade negotiations and market access for Canada's lobster industry. This project will determine if lobsters can contract White Spot Disease by eating infected shrimp tissue. An additional temperature profile was added at the request of the CFIA, as results are needed for trade negotiations.

The study found lobster tissue was negative for the presence of WSD genetic material. Shrimp bioassay samples were positive. The positive shrimp bioassay corroborates the fact that the PCR-positive shrimp material contained viable WSD virus (note that a PCR-positive test result does not provide information concerning the viability of the positive material). WSD cannot be cultured in the lab using cell culture techniques traditionally used for finfish virus isolation and propagation. Further analysis is pending.

The conclusion based on the molecular and bioassay results is that, at 10°C, adult market sized lobster fed WSD-infected shrimp material do not appear to be susceptible to developing disease associated with WSD infection. Long term carriage of the WSD virus in asymptomatic (i.e., 'healthy') lobster also does not occur at 10°C.

APR. 2013–MAR. 2014

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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CONFIRMATION OF THE VIABILITY AND INFECTIVITY OF WSSV-INFECTED SHRIMP USED IN A FEED CHALLENGE TRIAL INVOLVING AMERICAN LOBSTER

This project is a continuation of previous work that involved a WSSV (White Spot Symptom Virus) challenge of market-sized lobster using WSSV-infected shrimp (frozen) in which the shrimp were fed to lobster. The WSSV-fed lobsters were found to be negative. This is not unexpected, as lobsters are not the primary host species. However, in order to ensure adequate titre had been used, there was a need to confirm the viability and virulence of WSSV in the infected shrimp used as food. The objective of this work is to demonstrate the infected shrimp used as food in the lobster trial contained a sufficient viral load to cause infection when fed to other shrimp, the typical host species for this virus.

The susceptibility of a commercial species (*Homarus americanus*) to WSSV, a CFIA and OIE reportable disease, will directly inform risk assessment and trade negotiations.

Shrimp in rearing facilities grown for the study. Photo: DFO

MAY 2014–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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(L-R) GBU – AAHL technician Phyllis Dixon (holding a lobster) and Danielle Gordon (Veterinary student) are examining a healthy American lobster (*Homarus americanus*) from a GBU aquatic animal holding unit. Live lobster are used to support an ongoing investigation that is evaluating the susceptibility and pathobiology of shrimp viral pathogens in lobster by using experimentally infected lobsters within the GBU high level biocontainment facility. Photo: DFO

THE USE OF RNAlater FOR THE INACTIVATION OF THE INFECTIOUS SALMON ANEMIA VIRUS

RNAlater (Ambion/Life Technologies) is perhaps the most well-known of the commercially available buffers for the protection of RNA, and has been found to completely stabilize the RNA in a variety of tissues and viruses. It is clear that RNAlater preserves nucleic acids in all tissue types. What is less clear is whether or not RNAlater provides protection to virus, or rather inactivates the virus while preserving its RNA. In 2005, the effects of RNAlater were tested on a variety of human viruses, and it was found that some viral preservation was possible. The research showed that following high level purification, the virus was still infectious.

A more important question is whether infected tissues remain infectious while in the presence of the RNAlater? To address this question, we are investigating the infectiousness of the Infectious Salmon Anemia Virus (ISAV) virus, which has been preserved in RNAlater. This project will determine if the product, RNAlater, kills the virus. This is important to support our laboratory biocontainment standards and quality management systems.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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DEVELOPMENT AND DIAGNOSTIC VALIDATION OF A qPCR ASSAY TO DETECT *MIKROCYTOS MACKINI*

Under the *Canadian Health of Animals Act* (HAA), the occurrence of *Microcytos mackini* must be reported to the Canadian Food Inspection Agency (CFIA). The overarching goal of this multi-year project is the development and validation of a molecular diagnostic test for the listed pathogen of Pacific Oyster (*Crassostrea gigas*), *M. mackini*. The main aims of this study, which have been addressed sequentially since this project's inception in 2007, are as follows: (1) to isolate a new, more quickly evolving genetic region to use for molecular diagnosis of *M. mackini* (completed); (2) to survey extant diversity of *M. mackini* throughout its range to ensure appropriate specificity of the new assay (completed); (3) to develop a sensitive and specific real-time PCR assay for this pathogen (completed); (4) to complete full diagnostic validation of this assay (in progress); and (5) to publish the work (not completed).

This phase of the work will lead to publication of the new qPCR assay to detect *M. mackini*. Its analytical and diagnostic characteristics will be fully assessed. Information on its performance is required to support its use for testing under National Aquatic Animal Health Program (NAAHP) within Canada, as well as its use internationally.

MAY 2007–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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MEGALOCYTIVIRUS/RED SEA BREAM IRIDOVIRUS QUANTITATIVE PCR ASSAY DEVELOPMENT: PHASE I – MEGALOCYTIVIRUS ISOLATE COLLECTION, VIRUS AMPLIFICATION, AND STAKEHOLDER CONSULTATION

The pathogen Red Sea Bream Iridovirus has been detected in over 30 species of wild and cultured marine and freshwater fish. International trade in live ornamental fish is considered a major route of entry for megalocytiviruses into new geographical areas. This pathogen has been identified by the Canadian Food Inspection Agency (CFIA) as a potential emerging disease that is now present in the United States.

The goal for the Megalocytivirus/Red Sea Bream iridovirus Phase I (i.e., 2014–15 of this project) is to collect and bioamplify isolates that will be used to establish the analytical specificity of the assay (e.g., isolates belonging to the *Iridoviridae* family or viruses co-localizing to the target tissue). In Phase II (i.e., 2015–16), a qPCR assay(s) will be developed for detection of megalocytiviruses and/or RSIV. The long-term goal of the project is validation of the molecular assay according to World Organization for Animal Health (OIE) standards and harmonization of this methodology for the detection of megalocytiviruses and/or RSIV in diagnostic labs across Canada and eventually in other countries as well.

Canada now has a collection of RSIV isolates that are required to support testing under the National Aquatic Animal Health Program (NAAHP) within Canada. They will also be made available for use internationally.

MAY 2013–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

PROJECT LEAD: Sharon Clouthier (DFO)

PROJECT TEAM: Tamara Schroeder, Adrian Zetner (DFO)

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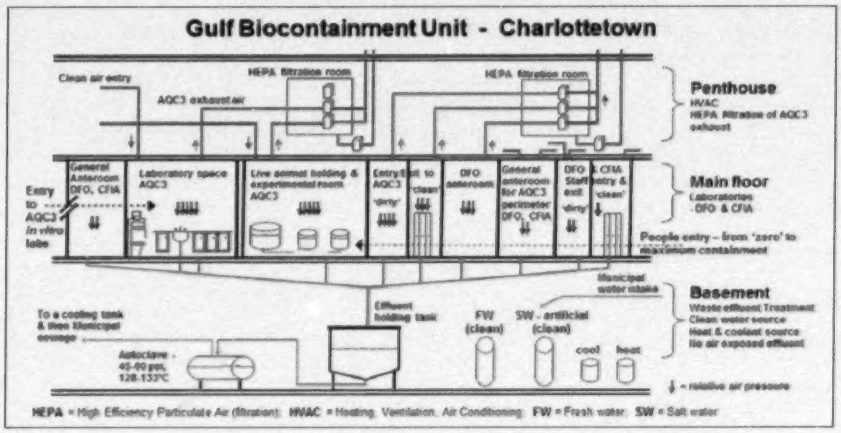
ESTABLISH AN EXPERIMENTAL HOST-PATHOGEN MODEL INVOLVING RED SEA BREAM IRIDOVIRAL DISEASE AGENT (RSIV) IN FINFISH AND PRODUCE RSIV-INFECTED TISSUE

Red Sea Bream iridoviral disease (RSIV) is a significant cause of mortality of Red Sea Bream (*Pagrus major*) and dozens of other species. It is a reportable disease under the National Aquatic Animal Health Program (NAAHP), and the National Aquatic Animal Health Laboratory System (NAAHLS) is required to develop a validated assay for this pathogen. As RSIV propagation by cell culture is not always effective, alternative means of producing positive material for use in validation are required. The Gulf Biocontainment Unit – Aquatic Animal Health Laboratory (GBU-AAHL) will use injection trials to try and produce positive material for use in subsequent assay validation.

Virus derived from this type of initial animal trial can then be harvested and prepared for more elaborate animal-based trials as needed as well as properly characterized and titred using molecular techniques.

MAY 2013–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)


Gulf Biocontainment Unit - Charlottetown
HEPA filtration room
Clean air entry
AQC3 exhaust air
HEPA filtration room
Penthouse
HVAC
HEPA filtration of AQC3 exhaust
General Anteroom DFO, CFIA
Laboratory space AQC3
Live animal holding & experimental room AQC3
Entry/exit to AQC3
DFO anteroom
General anteroom for AQC3 perimeter DFO, CFIA
DFO & CFIA Staff entry & exit
Entry to AQC3 in vitro labs
'dirty'
'clean'
Main floor
Laboratories - DFO & CFIA
People entry – from 'zero' to maximum containment
Municipal water intake
Basement
Waste effluent Treatment
Clean water source
Heat & coolant source
No air exposed effluent
Effluent holding tank
To a cooling tank & then Municipal sewage
FW (clean)
SW - artificial (clean)
cool
heat
Autoclave - 45-60 psi, 128-133°C
↓ = relative air pressure
HEPA = High Efficiency Particulate Air (filtration); HVAC = Heating, Ventilation, Air Conditioning; FW = Fresh water; SW = Salt water

Schematic representation of critical elements of biocontainment at the Gulf Biocotnainment Unit (GBU) in Charlottetown. The diagram portrays selected physical barriers including the precise management of room air pressure that enables directional air flows, HEPA-filtration of all exhaust air, multi-room entry/exit corridors (between areas of no containment and highest containment) and waste water sterilization in the basement using large autoclaves. GBU is certified to the highest level of biocontainment standard in Canada for work with aquatic animal pathogens and live animals, and is designated 'AQC3 *in vivo*'. This level of biocontainment is required for lab-based investigations where high risk imported pathogens are experimentally introduced into live animals and includes work with agents such as RSIV, White Spot Syndrome Virus (WSSV) and Salmon Alpha Virus (SAV). Photo: Phil Byrne (DFO)

PROJECT LEAD: Phil Byrne (DFO)

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REVERSE TRANSCRIPTION QUANTITATIVE POLYMERASE CHAIN REACTION (RT-qPCR) DIAGNOSTIC ASSAY FOR DETECTION OF SPRING VIREMIA OF CARP VIRUS (SVCV) – DIAGNOSTIC VALIDATION PHASE IIA (SAMPLE GENERATION AND DISTRIBUTION)

Melisa Lindsay (DFO) holding a Common Carp, *Cyprinus carpio*.

Spring viremia of carp, also known as acute infectious dropsy, is a highly contagious disease found primarily in cultured and wild populations of Common Carp, *Cyprinus carpio*. The causative agent Spring viremia of carp virus, (SVCV) has been found in Canada (Lake Ontario).

In general, mortality is most likely to occur in *Cyprinus carpio*, although Asian Carps may also develop the disease. SVCV can be extremely virulent (70–100% mortality) to juvenile carp in their first year and die-offs are typically observed in the spring when the water temperature is between 15 °C and 17 °C.

Phase I (i.e., 2013–14) of the project was to develop a molecular assay capable of detecting spring viremia of carp virus during the acute phase of the disease.

Phase II will be used to generate samples for use in validation of the molecular assay.

Information on the assay's performance is required to support its use for testing under National Aquatic Animal Health Program (NAAHP) within Canada, as well as to make it available for use internationally.

MAY 2013–APR. 2016

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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COLLABORATORS: Carol McClure (AVC)

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THE EPIDEMIOLOGY OF WINTER ULCER DISEASE IN FARMED ATLANTIC SALMON IN CANADA

The overall goal of this project is to better understand the epidemiology of *Moritella viscosa* on Atlantic Salmon fish farms on the East Coast of Canada.

Winter ulcer disease caused by *M. viscosa* is the primary reason for antibiotic usage in aquaculture on the east coast of Canada. Anecdotal reports suggest mortality from this disease is increasing and it is unknown whether this is due to treatment resistance, increased virulence, reduction in host immunity, increased exposure, or a combination of these factors.

Identification of risk factors for this disease and management strategies to control the bacterial pathogen are needed to improve the sustainability of the industry. To date, there is no published descriptive epidemiology for *M. viscosa* in Canada. This basic information is essential for developing hypotheses on control and prevention strategies.

Specific objectives are to: (1) describe disease outbreaks with respect to specific environmental and husbandry factors at pen and farm levels; (2) assess antibiotic treatment efficacy for this pathogen over the last five years; and (3) develop a proposal to address potential management strategies for vaccination and treatment applications, based on the epidemiology of the disease.

SEP. 2014–JUN. 2015

FUNDED BY: Canada Excellence Research Chair (CERC) – Aquatic Epidemiology, UPEI

PROJECT LEAD: Sophie St. Hilaire (UPEI)

PROJECT TEAM: Allison MacKinnon (Novartis)

COLLABORATORS: Novartis

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RAPID DETECTION OF REPLICATING INFECTIOUS SALMON ANEMIA VIRUS

Much of the aquaculture industry depends on regular diagnostic testing to assure the health of its animals. In the finfish aquaculture industry, viral pathogens are of particular concern, as they can cause significant mortalities. As such, fish are tested frequently.

RT-qPCR is a modern molecular technique that is rapidly gaining favour in diagnostic labs of all types, and is often used for the detection of the infectious salmon anemia virus. Perhaps the only drawback of this technique is that while it detects the nucleic acids of the virus, it provides no information regarding the replicative ability of the virus. In other words, both replicating and non-replicating viruses are detected; this can bring into question the biological significance of RT-qPCR findings. Conversely, classical viral isolation techniques provide strong evidence of replicating virus, but are generally slower, more labour intensive and less sensitive than RT-qPCR.

The current project seeks to combine the strongest aspects of both these techniques, while adding tweaks to the detection process, in an effort to modernize and improve upon our validated assays. We believe that fusion of proven classical techniques with modern molecular techniques will result in increased capacity and quicker turnaround times for testing labs.

DFO biologist, Mélanie Roy, preparing cells for viral isolation assays. Photo: Mark LaFlamme (DFO)

This project will provide a new more rapid testing option for use in certain conditions.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

PROJECT LEAD: Mark LaFlamme (DFO)

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DETERMINE IF THE PRESENCE OF HPRo GENOMIC MATERIAL (DETECTED USING RT-qPCR IS ASSOCIATED WITH THE CONCURRENT PHYSICAL PRESENCE OF VIRAL MATERIAL (I.E., DISTINCT VIRIONS OR PARTIAL VIRUS ASSEMBLY, EVIDENCE OF VIRUS REPLICATION AND LOCALIZED TISSUES OR CELL-SPECIFIC PATHOLOGICAL CHANGES) THAT IS CONSISTENT WITH INFECTIOUS SALMON ANAEMIA VIRUS (ISAV)

The causative agent of infectious salmon anemia (ISA) is the ISA virus (ISAV). ISAV affects mainly Atlantic Salmon (*Salmo salar*). It is a Canadian Food Inspection Agency (CFIA) as well as World Organization for Animal Health (OIE) reportable disease. Both virulent and non-virulent forms of the virus exist, the latter often is identified as HPRO. To date HPRO has only been detected successfully using molecular techniques. This limitation has proven problematic for regulatory bodies as molecular tests are not conclusive in determining if a virus is viable, thereby making risk assessments and regulatory decisions regarding HPRO ambiguous at best. Adding to the complexity of the issue is the unknown link between HPRO and virulent forms of the virus.

This project proposes to bring together several testing approaches in order to help to visualize HPRO using more informative traditional methods such as transmission electron microscopy. In order to successfully apply traditional methods, a population with a high prevalence of HPRO must be found. The objective for the first phase of the project is to identify a suitable population for study. If this research is successful, the definitive identification of ISAV HPRO would inform the diagnostic approach used for HPRO as well as facilitate risk assessments, not only for Canada's NAAHP, but also for other countries.

MAY 2013–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

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PROJECT TEAM: Nellie Gagné (DFO)

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DEVELOPMENT OF ARTIFICIAL REFERENCE MATERIAL FOR ASSESSING IHNV AND VHSV RT-qPCR ASSAYS

A quantitative polymerase chain reaction (PCR) machine, used to detect Viral Hemorrhagic Septicemia Virus (VHSV) genetic material. Photo: DFO

The use of artificial positive control (APC) have an advantage over traditional controls because they are unrelated to the target pathogen and can be easily differentiated from each other thereby facilitate the identification of false positive results. RNA transcripts generated from APC are also ideal candidates for use in proficiency testing panels.

To this end, the aims of this project are threefold: (1) Establish procedures for generating large batches of IHNV and VHSV artificial reference material (ARM) for use as standards, controls, and proficiency testing; (2) identify optimal storage practices and shelf life of bulk reference materials; and (3) develop characterization procedures for IHNV and VHSV bulk reference materials.

Results from small scale pilot studies at the DFO Pacific Biological Station (PBS) Aquatic Animal Health Laboratory proved promising for proficiency testing of IHNV and VHSV RT-qPCR in that the artificial transcripts mimicked the biological target, could be accurately quantified, and present extremely low false positive. Due to the advantages of APC, a VHSV-APC has also been established. Other DFO National Aquatic Animal Health Laboratory System (NAAHLS) labs are beginning to implement the use of APC for other National Aquatic Animal Health Program (NAAHP) listed pathogens.

MAY 2014–MAR. 2015

FUNDED BY: DFO – Centre for Aquatic Animal Health Research and Diagnostics (DFO – CAAHRD)

PROJECT LEAD: Kyle Garver (DFO)

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ENVIRONMENTAL INTERACTIONS

- EVALUATING *BEGGIATOA* AND OPC AS INDICATORS OF BENTHIC HABITAT CONDITIONS ON HARD OCEAN SUBSTRATES USING VISUAL DATA COLLECTED SEASONALLY AT NEW FINFISH AQUACULTURE SITES AND NEAR THE END OF PRODUCTION AT ESTABLISHED SITES
- BENTHIC MONITORING OF HARD SUBSTRATES IN SALMON AQUACULTURE: FURTHER INSIGHT ON CURRENTLY USED INDICATOR TAXA IN BRITISH COLUMBIA
- ASSIMILATION CAPACITY OF ORGANIC MATTER FROM SALMON AQUACULTURE (ACOM): IMPROVING MODEL PREDICTIONS OF BENTHIC IMPACTS
- DEVELOPMENT AND VALIDATION OF ALTERNATIVE DETECTION METHODS FOR PERFORMANCE INDICATORS OF THE OXIC STATE OF BOTTOM SEDIMENTS
- IMPACT OF GLOBAL WARMING ON AQUACULTURE PRODUCTION IN LES ÎLES-DE-LA-MADELEINE: BLUE MUSSEL, SEA SCALLOP AND AMERICAN OYSTER
- ECOSYSTEM EXPERIMENT TO ASSESS ENVIRONMENTAL IMPACTS AND RECOVERY FROM FRESHWATER CAGE AQUACULTURE
- INTERACTIONS BETWEEN OFFSHORE MUSSEL CULTURE AND COMMERCIALLY IMPORTANT SPECIES: EVALUATION OF INDIRECT EFFECTS
- THE DEVELOPMENT OF A ROBUST METHODOLOGY FOR SULPHIDE PROBE CALIBRATION
- THE DEVELOPMENT OF ROBUST METHODOLOGY FOR SULFIDE PROBE CALIBRATION AND SEDIMENT SAMPLING
- CAN HARD CLAMS (*MERCENARIA MERCENARIA*) INCREASE THE RATE OF EELGRASS (*ZOSTERA MARINA*) RECOVERY IN AREAS IMPACTED BY OYSTER AQUACULTURE?
- DEVELOPING THE BENTHIC COMPONENT OF IMTA TO REDUCE THE IMPACT OF ORGANIC NUTRIENTS FROM FISH FARMS AND EVOLVING STANDARD OPERATING PROCEDURES
- WATER CIRCULATION, TRANSPORT, AND DISPERSAL IN GRAND MANAN ISLAND
- PREDICTIVE MODELING FOR PARALYTIC SHELLFISH POISONING IN BAYNES SOUND, BRITISH COLUMBIA
- EVALUATION OF BENTHIC FAR-FIELD AND SITE RECOVERY EFFECTS FROM AQUACULTURE WITHIN THE LETANG INLET, NEW BRUNSWICK
- VALIDATION OF DEPOMOD WITH A COMPARISON OF VISUAL TECHNIQUES FOR OBSERVING SPATIAL AND TEMPORAL VARIABILITY IN THE BENTHOS AT ACTIVE AND FALLOWED FINFISH SITES IN NEWFOUNDLAND
- FRESHWATER FINFISH CAGE AQUACULTURE: DEVELOPMENT OF SEDIMENT BIOGEOCHEMICAL INDICATORS FOR REGULATION OF FRESHWATER CAGE AQUACULTURE
- INFLUENCE OF EASTERN OYSTER AQUACULTURE ON EELGRASS POPULATIONS AND THEIR RECOVERY
- TO VALIDATE THE ROBUSTNESS OF THE ECOSYSTEM CARRYING CAPACITY MODELS BEING DEVELOPED FOR ST. PETER'S BAY
- INVESTIGATING TEMPORAL VARIABILITY IN MACROFAUNAL RECOVERY PROCESSES DURING FALLOW PERIODS AT FINFISH AQUACULTURE SITES IN NEWFOUNDLAND
- THE EFFECT OF CULTURED FILTER FEEDERS ON EELGRASS PRODUCTIVITY IN ESTUARIES OF NEW BRUNSWICK AND PRINCE EDWARD ISLAND
- EVALUATING THE EFFICACY OF THE FALLOWING PERIOD AS A MITIGATION TOOL AT THE PREDOMINANTLY HARD BOTTOM AQUACULTURE SITES IN NEWFOUNDLAND
- MANAGEMENT OF HUSBANDRY PRACTICES TO MAINTAIN WATER COLUMN ENVIRONMENTAL CARRYING CAPACITY FOR BIVALVE CULTURE
- COMPARING THE IMPACT OF BOTTOM AND SUSPENDED OYSTER CULTURE ON BAY-SCALE FOOD RESOURCES (FOXLEY/TROUT RIVER, PEI)
- DOSE-RESPONSE RELATIONSHIPS FOR MUSSEL CULTURE AND BENTHIC CONDITIONS
- BIOMASS OF THE BENTHIC INVERTEBRATE COMMUNITY AROUND FRESHWATER AQUACULTURE FARMS
- DEVELOPMENT OF MANAGEMENT ZONES FOR FINFISH AQUACULTURE IN BRITISH COLUMBIA. PHASE 1: DATA COLLECTION AND EVALUATION. PHASE 2: INFORMATION INTEGRATION TO PROVIDE ADVICE AND RECOMMENDATIONS IN SUPPORT OF FINFISH AQUACULTURE MANAGEMENT
- EXPLORATION OF METHODOLOGIES FOR ENVIRONMENTAL EFFECTS MONITORING OF FINFISH AQUACULTURE SITES IN SANDY BOTTOM ENVIRONMENTS WITH NATURAL DISTURBANCES: SHELBURNE, NOVA SCOTIA
- DEVELOPING HARD-BOTTOM INDICATORS FROM BRITISH COLUMBIA ARCHIVED BENTHIC VIDEO SURVEYS ASSOCIATED WITH THE AQUACULTURE ACTIVITIES REGULATIONS
- OCEANOGRAPHIC STUDY OF THE SOUTH COAST OF NEWFOUNDLAND

EVALUATING *BEGGIATOA* AND OPC AS INDICATORS OF BENTHIC HABITAT CONDITIONS ON HARD OCEAN SUBSTRATES USING VISUAL DATA COLLECTED SEASONALLY AT NEW FINFISH AQUACULTURE SITES AND NEAR THE END OF PRODUCTION AT ESTABLISHED SITES

The overall purpose of this project was to evaluate *Beggiatoa* (a type of aquatic bacteria) and Opportunistic Polychaete Complexes (OPC) as potential indicators of deposition around finfish aquaculture sites located over hard ocean substrates. The study was conducted on the south coast of Newfoundland (NL) and covered a wide range of substrate types from fine and medium sediments, to predominantly bedrock. Changes in abundance and diversity of benthic communities were observed in response to aquaculture waste deposition. The results of the study suggest that the status of the finfish site (baseline, production, fallow) had the strongest influence on the presence of *Beggiatoa* and OPCs, thereby making them acceptable indicators of the effects of aquaculture operations on the benthos. Their presence/absence correlated with other variables, including flocculent presence, off-gassing, and sulfides; however, *Beggiatoa* coverage did not increase linearly with sulfide level (Hamoutene, 2014). The abundance of *Beggiatoa* and OPC decreased as a function of distance from cage (used as a proxy for decreasing deposition) and also became patchier in distribution. The presence of indicators was observed at average distances ~70 m from cages, suggesting the need to extend sampling transects to at least 120 m (as opposed to 50 m in regulatory protocols) with stations separated by 20 to 30 m to properly delineate deposition areas.

Given the depauperate nature of some benthic environments and the persistent presence of indicators in others, more research is required to assess the effectiveness of fallowing periods as a management tool in Newfoundland.

APR. 2011–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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BENTHIC MONITORING OF HARD SUBSTRATES IN SALMON AQUACULTURE: FURTHER INSIGHT ON CURRENTLY USED INDICATOR TAXA IN BRITISH COLUMBIA

The use of indicator taxa for environmental impact monitoring requires in-depth knowledge and understanding of the biology and natural history of the species used. This research adds more knowledge that policy makers can utilize to create more informed management decisions.

Two indicator taxa are currently used in benthic monitoring of hard substrate finfish aquaculture sites in British Columbia, Canada: (1) the white filamentous mat-forming bacteria *Beggiatoa*; and (2) Opportunistic Polychaete Complexes (OPC). Both organismal groups have been observed in areas of high enrichment, yet many questions still exist surrounding what their presence is indicating. This research set forth to learn more about each taxon, and specifically what comprises each group when video footage is taken. *Beggiatoa* mats were sampled to measure abundance, biomass and types, with emphasis on correlations to percent coverage estimates and environmental variables. Quantified *Beggiatoa* amounts were found to have little correlation to percent coverage estimations, suggesting actual amounts of living bacteria are over- or under-estimated using visual methods only. OPC groups were sampled and identified using DNA sequencing, with molecular tools created for easier identification purposes without the need of highly-specialized taxonomists.

SEP. 2012–AUG. 2014

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COLLABORATORS: Creative Salmon; Marine Harvest Canada; Grieg Seafood; Cermaq; Mainstream Biological

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http://www.nic.bc.ca/about_us/research_innovation/current_research.aspx

ASSIMILATION CAPACITY OF ORGANIC MATTER FROM SALMON AQUACULTURE (ACOM): IMPROVING MODEL PREDICTIONS OF BENTHIC IMPACTS

This research project aims to increase scientific knowledge on the impact of biochemical oxygen demanding (BOD) matter effluents across a range of benthic habitats, including soft, mixed and hard bottoms. This knowledge is intended to increase competence in the prediction of benthic impacts and in the design of related monitoring programs.

The spatial scale, magnitude and persistence of benthic effects caused by BOD matter released from fish farms are influenced by a range of factors that control effluent deposition, recycling, and transport. Potential benthic community impacts associated with the release of BOD matter from net-pens have been assessed during site development using models that do not consider the inherent capacity of different benthic habitats to mineralize (recycle) this material without altering the natural oxic state of the sediments. This organic enrichment threshold is commonly referred to as the "assimilative capacity" of the seabed. This new multidisciplinary research project aims to increase scientific expertise and knowledge on the major physical, chemical, and biological processes that collectively determine a site's assimilative capacity. Field research programs have been designed to contribute the knowledge required to develop a new farm assessment model. The model will work with measured current data and output from an existing Finite-Volume, primitive equation Community Ocean Model (FVCOM) water circulation model to more accurately predict the spatial scale and magnitude of benthic impacts from fish farms.

JAN. 2014–MAR. 2017

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Peter Cranford (DFO)

PROJECT TEAM: Brent Law, Fred Page, Shawn Robinson, Herb Vandermeulen, Susan Haigh, Terri Sutherland (DFO)

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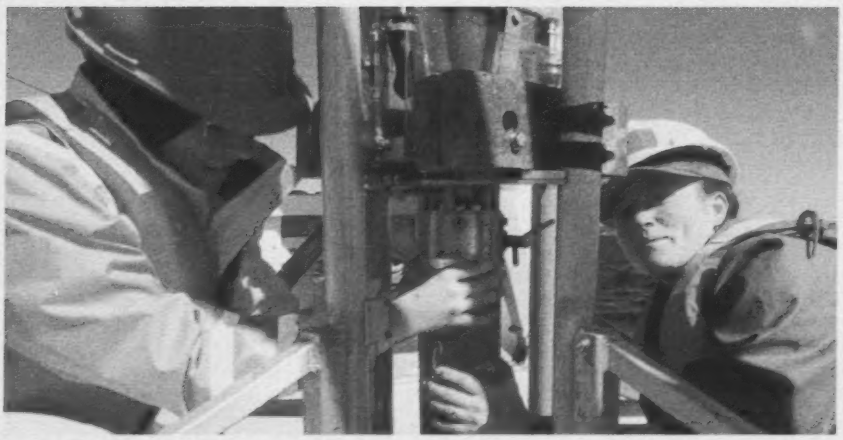
DEVELOPMENT AND VALIDATION OF ALTERNATIVE DETECTION METHODS FOR PERFORMANCE INDICATORS OF THE OXIC STATE OF BOTTOM SEDIMENTS



Lindsay Brager and Vanessa Zions collecting a core for assessing sediment oxic state near a salmon farm. Photo: Peter Cranford (DFO)

The intended outcome from this ongoing research is an increase in confidence in aquaculture regulatory monitoring program results and related management decisions.

Potential impacts associated with biochemical oxygen demanding (BOD) matter effluents from fish farms are currently assessed by monitoring the oxic state of the bottom sediment. Performance indicators, such as total "free" sulfide concentrations and Eh, are commonly used to determine the impact of BOD matter deposits. The electrochemical method for measuring sulfide has become the standard approach for aquaculture monitoring but may be less suitable (i.e., accuracy, labour, cost, etc.) than some alternative methods that are currently available. Concerns have also been raised about the possible effects of sample storage on the accuracy of the sulfide data being collected. The purpose of this ongoing research is to evaluate alternative detection methods of BOD matter impacts that are more accurate and less prone to error while remaining practical for industry. Preliminary work has focused on the testing of a field UV spectrophotometer that can rapidly measure sulfide levels onboard the sampling vessel immediately after sample collection. This method was selected as it eliminates the need for frequent instrument calibration, requires no chemicals and avoids problems with the possible loss of sulfide during storage. Other sulfide approaches (e.g., amperometric sensors, automated methylene blue) and BOD impact indicators (dissolved oxygen) are also under study.

JAN. 2014–MAR. 2016

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Peter Cranford (DFO)

PROJECT TEAM: Blythe Chang, Fred Page (DFO)

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IMPACT OF GLOBAL WARMING ON AQUACULTURE PRODUCTION IN LES ÎLES-DE-LA-MADELEINE: BLUE MUSSEL, SEA SCALLOP, AND AMERICAN OYSTER

The primary objective of this project is to assess the ability of marine aquaculture production in the Îles de la Madeleines to adapt to global warming. To achieve this objective, we studied the Blue Mussel (*Mytilus edulis*), the American Oyster (*Crassostrea virginica*), and the Sea Scallop (*Placopecten magellanicus*).

This project seeks to better understand the impact of global warming on marine aquaculture production and studies alternatives for producers. Aquaculture production of Blue Mussels, American Oysters, and Sea Scallops, is an industry that is essential to the economy of the islands. In recent years, the people involved in this industry have noted lower numbers of organisms in culture sites within lagoons. They also note that these numbers seem to coincide with the longer duration of temperatures above 20°C, with maximum temperatures recorded in the summer. For example, between 1995 and 1997, the water temperature in lagoons exceeded 20°C for an average period of 23 days, beginning in August, whereas this period lasted 58 days between 2007 and 2009, from mid-July onward. To answer the industry's questions about the effects of warmer waters at culture sites on production, and to help this sector deal with this new problem, it is important, as recommended by FAO, to consider alternatives that will ensure sustainable aquaculture management in the face of global warming. This research project was undertaken with these goals in mind. Its purpose is to establish connections between aquaculture yields, environmental characteristics at culture sites, trophic conditions in the environment, and individuals' physiological condition.

JUN. 2014–JUL. 2017

FUNDED BY: Fonds de Recherche du Québec Nature et Technologie (FRQNT); Fond d'Amorçage de Partenariat (FAP) (UQAR, Merinov)

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PROJECT TEAM: Madeleine Nadeau, technicians/workers (Merinov's Centre des-Îles)

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Preparing equipment for sampling. Photo: Jacques Richard

ECOSYSTEM EXPERIMENT TO ASSESS ENVIRONMENTAL IMPACTS AND RECOVERY FROM FRESHWATER CAGE AQUACULTURE

Researchers at the Experimental Lakes Area (ELA) operated an experimental Rainbow Trout farm (L375) from 2003–2007. For a period of two years prior to production, throughout production, and for two years after production, L375 and the control lake (L373) were closely monitored. By the fourth and fifth years of fish production, there was a substantial decrease in benthic invertebrate density and diversity along the entire 100 m transect from the fish cage, and increases in water column total phosphorus and algal production. The wild Lake Trout population in L375 responded to cage culture with improved condition, increased survival, increased reproduction, and over the 5 years of production, the population size nearly doubled. The forage fish community, which was not as closely monitored as Lake Trout, showed increased catch per unit effort for many species. The purpose of this extension to the project is to enable researchers to continue the monitoring of the recovery of those ecosystem components that showed the most response to aquaculture activities. Of these, the effects of aquaculture on sediments are currently of particular interest due to the intention of regulatory agencies to add sediment monitoring to commercial cage license conditions. The monitoring of the recovery of sediments under the ELA farm will provide a valuable opportunity to measure the rate of removal of waste material through assimilative processes.

APR. 2010–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Northern Ontario Aquaculture Association (NOAA)

PROJECT LEAD: Cheryl Podemski (DFO)

COLLABORATORS: Northern Ontario Aquaculture Association (NOAA)

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

INTERACTIONS BETWEEN OFFSHORE MUSSEL CULTURE AND COMMERCIALLY IMPORTANT SPECIES: EVALUATION OF INDIRECT EFFECTS

A lobster checks out an experimental mesocom in Îles de la Madeleine. Photo: Chris McKindsey (DFO)

Benthic macrofauna (e.g., crabs, flounder, lobster) are often more abundant in mussel culture sites than in areas surrounding them. It is unknown what effects this has on the productivity of these organisms. It has been suggested that changes in infaunal communities (the worms, clams, and so on that live in bottom sediments) due to organic loading from mussel culture may have cascading effects on the animals that eat these organisms. This study is evaluating the indirect effects of mussel culture on crabs and flounder through a series of manipulative experiments. In short, a series of cages were set up on the sea floor below an offshore mussel farm and in areas outside of the farm in Îles de la Madeleine, Quebec. Another experimental set-up used cages on the bottom in which organic loading rates were modified to alter benthic communities. In both cases, crabs or flounder were placed in the cages, allowed to feed on existing resources for about 1 week, and then sampled to evaluate what the organisms eat in the different areas using gut content analysis. We then determined how the available resources influenced their instantaneous growth rates by using biochemical indicators (RNA:DNA ratios) and measuring otolith (fish inner ear bone) growth rates. This work will determine if mussel sites solely aggregate benthic macrofauna or if the sites may also have cascading effects on their productivity.

APR. 2013–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** La Société de développement de l'industrie maricole (SODIM); Ressources Aquatiques Québec (RAQ); Université du Québec à Rimouski (UQAR)

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THE DEVELOPMENT OF A ROBUST METHODOLOGY FOR SULPHIDE PROBE CALIBRATION

Environmental monitoring of finfish aquaculture industries in New Brunswick, Nova Scotia, and British Columbia relies on the measurement of sediment sulphide concentrations to detect adverse environmental impacts from finfish farming over soft-sediment substrates. There are often, however, wide variations in sulphide values taken from samples at the same farm and even among triplicate subsamples taken under the same cage. These differences may be due to the variability in sulphide probe calibrations. The aim of this project was to develop a methodology for consistent sulphide probe calibration. Laboratory studies were conducted on the different parameters that were thought to be contributing to the variability observed in probe calibration. Standardization of procedures developed through this project are helping to ensure that the use of sulphide probes in environmental monitoring for the Canadian finfish aquaculture industry is as consistent, reliable, and accurate as possible.

The results from this study have contributed to clarifying some issues related to the methodology for sulphide probe calibration. However, other questions remain and this research will be continued to include additional work on laboratory protocols, as well as to examine issues related to sediment sample collection, transport, storage, handling, and analysis.

APR. 2013–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Atlantic Canada Fish Farmers Association (ACFFA); Sweeney International Marine Corp. (SIMCorp)

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

THE DEVELOPMENT OF ROBUST METHODOLOGY FOR SULFIDE PROBE CALIBRATION AND SEDIMENT SAMPLING

The results of this project can contribute to the development of a reliable, accurate, consistent, and robust methodology for sediment sampling, which could be adopted by Provincial regulators.

Environmental monitoring of marine finfish aquaculture operations in New Brunswick, Nova Scotia, and British Columbia rely on the measurement of sulfide concentrations in sediment (within farm leases) as the fundamental indicator of adverse environmental impacts from finfish farming at soft bottom sites. Government departments in NB, NS, and BC have established their own Standard Operating Procedures (SOPs) to evaluate the aquaculture industry's environmental impact. Comparisons among the SOPs indicate several differences among regions, which c ould lead to differing results.

Previous research has revealed that the standard solutions ("standards") used in sediment sulfide monitoring degrade significantly over time and that probe accuracy also degrades over time (post-calibration). These results suggest the need for additional research on sediment sulfide methodologies including possible changes in probe accuracy following their use in sediments with high sulfide concentrations and the effects of salinity on these standards. This research project will also examine potential sources of error related to the methods used in the collection, storage, transportation, and handling of sediment samples.

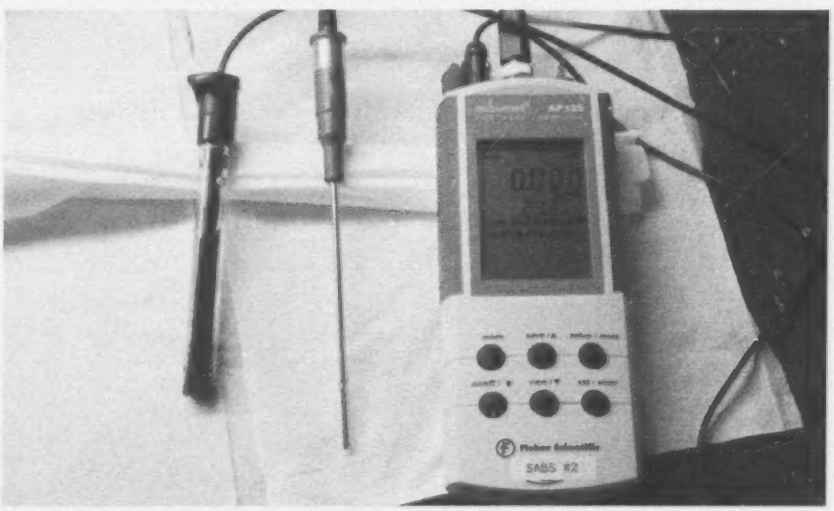

Photo shows sulfide probe, temperature probe, meter (left to right). Photo: Fred Page (DFO)

APR. 2014–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Atlantic Canada Fish Farmers Association (ACFFA); Sweeney International Marine Corp. (SIMCorp)

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CAN HARD CLAMS (*MERCENARIA MERCENARIA*) INCREASE THE RATE OF EELGRASS (*ZOSTERA MARINA*) RECOVERY IN AREAS IMPACTED BY OYSTER AQUACULTURE?

The strategies tested in this study may promote the development of environmentally-friendly practices for the aquaculture industry by mitigating the negative impacts of active leases and eliminating the impacts of those sites no longer in use.

Eelgrass communities are declining in many areas of the world, mainly due to increased inputs of nutrients and sediments from land-based sources, but also due to shading from aquaculture structures. Enhancement activities such as manual seed dispersal and transplanting whole plants have been explored to help counter eelgrass habitat declines, but with limited success at a substantial cost. Bivalves have been found to stimulate eelgrass growth by clarifying the water column, thereby increasing light availability and increasing nitrogen levels through the production of waste products (faeces, pseudofaeces). This project aims to determine whether the seeding of hard clams (*Mercenaria mercenaria*) can enhance eelgrass recovery in areas impacted by oyster aquaculture. Various densities of hard clams will be introduced to areas with bare or sparse patches of eelgrass due to shading from previous commercial off-bottom oyster operations. Sediment characteristics, such as porosity (the empty space between sediment particles), organic content, and carbon/nitrogen levels will be monitored along with the growth and recovery of the eelgrass over three years. Additionally, clams will be sown directly under lines of suspended oyster bags at an active aquaculture site, to determine if their presence will encourage the growth of eelgrass populations in this heavily-impacted area.

APR. 2014–MAR. 2017

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** L'Étang Ruisseau Bar Ltd.

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PROJECT TEAM: André Mallet (L'Étang Ruisseau Bar Ltd.); Claire Carver (Carver Marine Consulting); Marie-Hélène Thériault (DFO)

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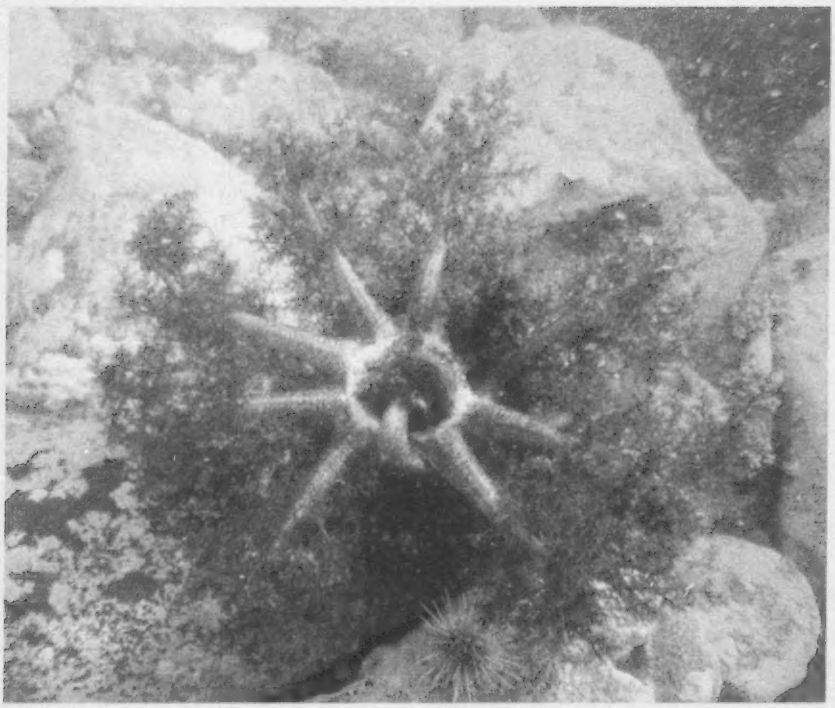
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

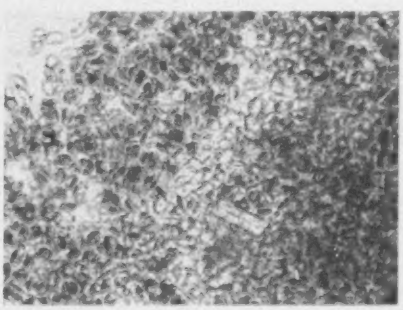
Oysters on the seafloor in an eelgrass bed. Photo: Luc Comeau (DFO)

DEVELOPING THE BENTHIC COMPONENT OF IMTA TO REDUCE THE IMPACT OF ORGANIC NUTRIENTS FROM FISH FARMS AND EVOLVING STANDARD OPERATING PROCEDURES



Sea cucumber (*Cucumaria frondosa*). Photo: Shawn Robinson (DFO)

Fiberglass plates that will be used for the settling of larval sea urchins once they are produced in the hatchery and are ready for metamorphosis. Photo: Shawn Robinson (DFO)



Close-up of the diatoms coating the juvenile settling tank plates. Photo: Shawn Robinson (DFO)

This project will provide basic information on the feasibility for the development of the benthic component for IMTA where it is anticipated that the bulk of the assimilation of waste IMTA nutrients will occur.

Integrated multi-trophic aquaculture (IMTA) has been developing over the last decade in Canada and has mostly focused on the pelagic component. While the pelagic filter feeding role has a place in the IMTA system for economic diversification and some assistance in the control of fine particulates, pathogens, and parasites affecting the farm, they are not capable of feeding on the larger particle sizes where the bulk of the waste nutrients reside. The larger particles can be consumed by benthic species which still have to be developed for IMTA systems. The goal of this project is to investigate the production of three candidate species for the benthic component: the Green Sea Urchin (*Strongylocentrotus droebachiensis*), the Northern Sea Cucumber (*Cucumaria frondosa*), and the Sea Scallop (*Placopecten magellanicus*). These organisms will be studied for their ability to successfully exploit the organic nutrients coming from salmon farms as well as the efficiency of various containment structures (e.g., cages and nets) to house them. In addition to the basic culture information for the species, baseline data will also be gathered on the presence of any known fish pathogens that may be associated with IMTA practices for these species. The small, experimental crop that is produced during this research will be evaluated for product safety and marketing attributes.

APR. 2014–MAR. 2017

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Kelly Cove Salmon Ltd.

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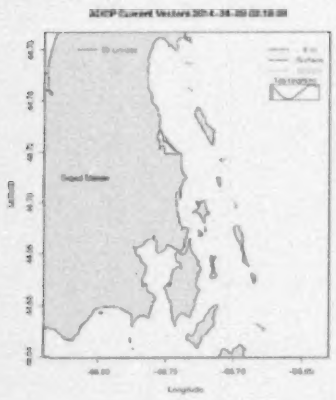
WATER CIRCULATION, TRANSPORT, AND DISPERSAL IN GRAND MANAN ISLAND



Screen capture of an animation... showing the current speed and direction at five current meter deployment locations, at three different depths: near surface; mid depth (six meters below the surface); and near bottom. The animation utilizes actual current meter data and cycles over one tidal cycle (12.4 hours), starting just after midnight on April 9th, 2014. Animation credit: Randy Losier (DFO)

Results of this research will be useful for bay management designations in the area and will inform decisions regarding fish health related to the management of parasites such as sea lice, as well as diseases and viruses including Infectious Salmon Anemia Virus (ISAV).

The majority of salmon farms in the eastern Grand Manan Island area (New Brunswick) were stocked in 2013. Having large numbers of fish stocked in this area has raised some questions about possible impacts to fish health management of the aquaculture industry and interactions with traditional fisheries. Under this research project, researchers collected additional oceanographic data using current meters to provide important information about water circulation, transport, and dispersal of disease vectors, parasites, and treatment products in the area.

This project has resulted in improved understanding of water circulation in the eastern Grand Manan Island area. This will inform decisions regarding Aquaculture Bay Management Area boundaries, farm production levels, and aquaculture-fisheries interactions. The improved knowledge on water circulation will also aid in fish health management, including determining timing of treatments for sea lice. Future work should look at seasonal variations, as well as explore other geographical areas.

APR. 2013–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP)
CO-FUNDED BY: Atlantic Canada Fish Farmers Association (ACFFA)

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PREDICTIVE MODELING FOR PARALYTIC SHELLFISH POISONING IN BAYNES SOUND, BRITISH COLUMBIA

The results of this research will help improve the overall sustainability of the aquaculture industry in British Columbia (BC) by facilitating decision making by the department on aquaculture siting, as well as allowing the aquaculture industry to plan harvests and avoid costly product recalls.

Paralytic shellfish poisoning (PSP) is a potentially lethal condition that is caused by the consumption of shellfish which have concentrated paralytic shellfish toxins (PST) from phytoplankton. This project explored the development of a predictive model to help identify and predict where and when phytoplankton blooms might occur. Various environmental and hydrographic data relevant to Baynes Sound, BC, were compiled and relationships between these factors and PSP events were evaluated using statistical analyses (correlations). The most important factors in predicting PSP levels were time of the year, salinity, and rainfall pattern. Specifically, the amount of measurable rain that fell three and four days prior to sampling was found to correlate with PSP levels. The PSP hindcast model predictions were shown to be accurate 97% of the time, making this a valuable real-time tool to help identify periods of increased risk to shellfish culture.

Aerial view of Bayne's Sound, BC. Photo: Gordy McLellan (Mac's Oysters Ltd.)

APR. 2011–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Mac's Oysters Ltd.

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Shellfish raft aquaculture in Metcalf Bay, BC. Photo: Robert Marshall

EVALUATION OF BENTHIC FAR-FIELD AND SITE RECOVERY EFFECTS FROM AQUACULTURE WITHIN THE LETANG INLET, NEW BRUNSWICK

The research is expected to yield information on the status of the far-field benthic environment within the Letang Inlet's aquaculture region in a temporal and spatial context before and after the implementation of Bay Management practises. New data will also shed light on long-term recovery at a site with discontinued farm operations.

The Letang Inlet, within the lower Bay of Fundy, is a marine tidal inlet where aquaculture of marine fish, specifically Atlantic Salmon, has occurred since the 1980s. A multi-year project (2012–2016) is being undertaken in cooperation with industry, government, and NGOs to evaluate far-field effects of salmon aquaculture in view of a baseline study undertaken in the 1990s within the same area. The objective is to document, compare, and evaluate current conditions with those of two decades earlier in light of various mitigating measures undertaken since, including the reduction of operational sites, establishment of treatment sites and protocols, and bay management fallowing procedures.

The study is based on benthic macrofaunal assemblages and environmental parameters sampled annually in the fish farming areas of Limekiln Bay and Bliss Harbour, and an un-farmed reference area. The work encompasses a full fallowing cycle in order to evaluate the potential effects of operating years 2013 and 2014 on Bay-wide cessation of operations within the Letang Inlet in 2012 and 2015. In addition, an assessment of long term recovery at a single site not in operation since 1998, but within an area of intense fish farm farming, will be undertaken using base line data from 1995–2000.

MAR. 2012–APR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Northern Harvest Sea Farms

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

Gerhard Pohle taking a water sample during field work on board the *Viola M. Davidson*. Photo: Andrew Cooper (DFO)

VALIDATION OF DEPOMOD WITH A COMPARISON OF VISUAL TECHNIQUES FOR OBSERVING SPATIAL AND TEMPORAL VARIABILITY IN THE BENTHOS AT ACTIVE AND FALLOWED FINFISH SITES IN NEWFOUNDLAND

The majority of Newfoundland finfish aquaculture sites are located in deep waters over hard bottom substrates. The current monitoring programs were based on the assumption that these sites would not be depositional. As organic deposition has been found to accumulate at some sites, this study aimed to evaluate the depositional model DEPOMOD (and the data inputs required for this model) as a monitoring tool for finfish aquaculture sites in Newfoundland.

Water current speeds in the study area were found to be quite variable. Using DEPOMOD predictions, carbon deposition was expected to be highest at the edge of the cage array, with drastically decreased deposition at 25 m away and further. Small amounts of deposition were also predicted at 50 m and 100 m from t he cage. Additionally, a variety of physical and biological processes (food and water content, food digestibility, carbon content of food and feces, and settling velocity for food waste and for feces) were identified and varied within the depositional model.

While DEPOMOD has been shown to be a potentially useful tool in predicting organic deposition on hard bottom sites, further analysis should be done at additional sites and throughout different stages in the production periods to further validate its use under a wider variety of environmental conditions found in Newfoundland.

APR. 2010–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Northern Harvest Sea Farms; Cold Ocean Salmon Inc.

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FRESHWATER FINFISH CAGE AQUACULTURE: DEVELOPMENT OF SEDIMENT BIOGEOCHEMICAL INDICATORS FOR REGULATION OF FRESHWATER CAGE AQUACULTURE

Benthic macroinvertebrates contribute to chemical and microbial in-sediment processes. They play a major role in waste assimilation and the transfer of carbon and energy from aquaculture waste to higher trophic levels within lake ecosystems. The deposition of biochemical oxygen demanding (BOD) matter from freshwater finfish cage farms impacts directly on the abundance and diversity of benthic invertebrate assemblages found in the immediate vicinity of the cage. Benthic invertebrates are typically used as indicators of benthic condition, however, sample collection and taxonomic identification within a monitoring program framework is both time consuming and costly. The objective of this project is to identify biogeochemical thresholds associated with major changes in abundance and community structure, which can be used to develop regulatory thresholds to manage deposit of aquaculture waste at levels that would maintain an acceptable degree of benthic alteration.

This knowledge will support the assessment of risk associated with the deposits of BOD material, and will contribute to the development of regulatory standards and monitoring protocols for aquaculture-affected sediments. It will also be of use in informing fallowing practices for freshwater aquaculture by identifying potential sediment recovery targets.

MAR. 2015–MAR. 2017

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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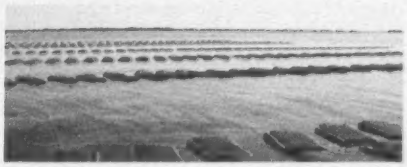
INFLUENCE OF EASTERN OYSTER AQUACULTURE ON EELGRASS POPULATIONS AND THEIR RECOVERY

Oyster culture in the Gulf of St. Lawrence, New Brunswick occurs almost exclusively in near-shore waters of bays and estuaries (in water depths of less than 5 metres), a range that directly overlaps with eelgrass (*Zostera marina*) habitat. Increased shading associated with oyster culture activities has been shown to negatively impact eelgrass growth and survival. This project aimed to determine the extent and rate of recovery of eelgrass exposed to suspended bag and bottom table oyster culture in the Southern Gulf of St. Lawrence in order to develop best management practices for minimizing impacts to the benthic habitat.

No substantial signs of recovery were evident 216, 632 or 794 days after removal of oyster aquaculture equipment for suspended bags, table culture at existing sites, or table culture at new aquaculture sites, respectively. Small canopy heights, however, were noted for certain groups, indicating that seeding recruitment did occur; however it did not appear that recruited seedlings survived to maturity. More research is required to fully evaluate this finding.

This study has provided crucial information on the spatial and temporal extent of eelgrass recovery exposed to excessive benthic shading from both suspended bag and bottom table oyster culture in the southern Gulf of St. Lawrence. The knowledge gained through this research will aid in the development of best management practices to minimize and mitigate the effects of oyster aquaculture. It will also guide the best placement of oyster tables in successive years to minimize the cumulative impacts to the benthic habitat (specifically eelgrass).



Suspended oyster aquaculture site in St-Simon Bay, New Brunswick. Photo: Marc Skinner (DFO)

APR. 2010–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (ACRDP) **CO-FUNDED BY:** L'Étang Ruisseau Bar Ltd.

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TO VALIDATE THE ROBUSTNESS OF THE ECOSYSTEM CARRYING CAPACITY MODELS BEING DEVELOPED FOR ST. PETER'S BAY

The goal of the project is to assess whether the removal of phytoplankton by densely stocked mussels in St. Peter's Bay (PEI) has exceeded the capacity of the ecosystem to renew phytoplankton populations. In this project, the robustness of the models developed as part in a previous study will be validated in Malpeque Bay. Although the total area allocated to mussel farming is similar in the two bays (~ 600 ha), the watershed volume is higher in Malpeque Bay (592,000,000 m^3 vs. 40,000,000 m^3). Other distinctive features include an intricate river system running into Malpeque, and multiple connection points between Malpeque and the Gulf of St. Lawrence. Together these features represent a challenging and therefore suitable environment to validate the ongoing development of ecosystem models for shellfish aquaculture. A second rationale for the project relates to the management of aquaculture in a proactive manner. The PEI Lease Management Board is engaged in a planning exercise regarding any future releases of acreage in Malpeque Bay for mussel culture. The results from this project will help identify the optimal distribution and configuration of new leases within the bay.

APR. 2011–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Luc Comeau (DFO)

PROJECT TEAM: Michel Starr, Liliane St-Amand, Thomas Guyondet, Rémi Sonier (DFO); Jonathan Grant, Ramón Filgueira (Dalhousie U)

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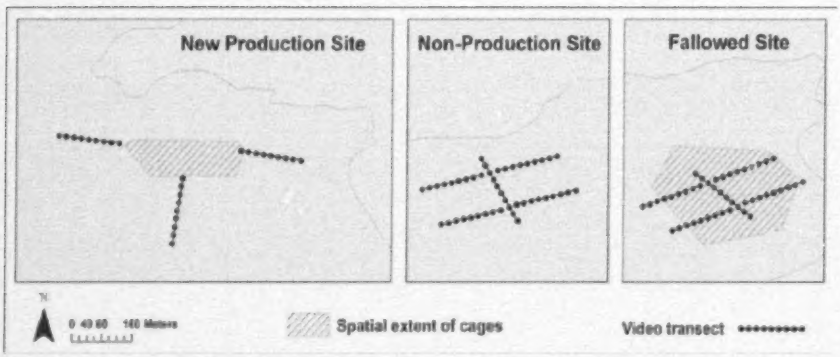
INVESTIGATING TEMPORAL VARIABILITY IN MACROFAUNAL RECOVERY PROCESSES DURING FALLOW PERIODS AT FINFISH AQUACULTURE SITES IN NEWFOUNDLAND



Sampling design for production, control, and fallow sites. The dots represent locations where underwater video was recorded.

The Newfoundland salmon farming industry is located primarily in the Coast of Bays region, on the south coast of the island. This area is characterized by fjords of over 100 m in depth and protected bays, with benthic substrates characterized by rock and cobble along with patchy areas of deposition. The study utilized visual surveys of the seafloor (using video transect sampling as an alternative to sediment-based techniques) to assess aquaculture impacts on the benthos within the challenging Newfoundland environment.

The video transect data revealed that the natural benthic macrofaunal communities in the south coast of Newfoundland are characterized by low abundances, however, organic enrichment from aquaculture was found to cause changes in the benthic environment. These changes were complex and highly variable, likely dependent on farming practices, environmental factors, and the capacity of the environment to process organic material.

This research has provided confirmation that benthic macrofaunal communities in Newfoundland are primarily living on rocky and patchy substrates. Additionally, it has revealed novel information on some recovery processes of the benthic community in deep water, hard substrate aquaculture sites. Further investigation is needed on lengths and usefulness of fallow periods in light of the low natural abundances of some benthic communities in Newfoundland. The results of this research will help inform regulation and support the sustainability of the Canadian aquaculture industry.

APR. 2011–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Cold Ocean Salmon; Northern Harvest Sea Farms

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Photo taken during DFO field research in the Coast of Bays region of Newfoundland. Photo: Kimberley Burt (DFO)

THE EFFECT OF CULTURED FILTER FEEDERS ON EELGRASS PRODUCTIVITY IN ESTUARIES OF NEW BRUNSWICK AND PRINCE EDWARD ISLAND

The complex nature of interactions in the coastal zone between farmed and wild stocks of American Oyster and Blue Mussels, and nutrient dynamics, can obscure the net habitat effects of bivalve aquaculture on habitats (CSAS-SAR 2006/005). Environmental effects of shellfish aquaculture on eelgrass and its function as fish habitat are associated with sedimentation, turbidity/shading, nutrients, flow patterns, and physical damage or removal. Shading from oyster aquaculture gear has been associated with a reduction in eelgrass productivity at a local scale. However, there is a knowledge gap related to potential counteracting effects of cultured bivalve biomass in improving the overall eelgrass productivity by influencing bay scale turbidity patterns resulting from natural and cumulative anthropogenic sources.

This study will examine the effects of cultured bivalves on eelgrass productivity at a bay scale. This will be achieved through field studies by characterizing the landscape and seascapes of four cultured bays with a focus on shellfish populations (wild and cultured) and eelgrass beds. A laboratory study will evaluate the rates at which mussels and oysters filter water, and the resulting effect on turbidity, seston, and light attenuation. Modifications to the existing hydrodynamic models will be developed for the region to include turbidity, sedimentation, and re-suspension. It will also incorporate the results of the lab-derived clearance rates of mussels and oysters, to allow for estimates of bay-scale effects from existing (or proposed) shellfish leases.

MAR. 2014–MAR. 2017

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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EVALUATING THE EFFICACY OF THE FALLOWING PERIOD AS A MITIGATION TOOL AT THE PREDOMINANTLY HARD-BOTTOM AQUACULTURE SITES IN NEWFOUNDLAND

This project sets out to examine the recovery processes at aquaculture sites undergoing different periods of fallowing by evaluating how the length of the fallowing period influences the distribution of the bio-indicators, *Beggiatoa* and Opportunistic Polychaete Complexes (OPC). Results of the CSAS process, 'Potential Impacts of Finfish Aquaculture on Hard Bottom Substrates and Development of a Standardized Monitoring Protocol' (CSAS-SAR 2014/017) indicated that these were acceptable indicators of organic deposition over a range of substrates. This study will also examine changes in flocculent matter and impacts on non-indicator species change during fallowing. The biological basis of changes in OPC distribution during fallowing will be examined to determine if *Beggiatoa* and OPC distributions change in a predictable manner across aquaculture sites on the south coast of Newfoundland. Multivariate statistics will be used to characterize important factors associated with changes in the distribution of bio-indicators and the composition of epifauna.

The outcome of this research will improve our understanding of the processes of fallowing in the Newfoundland and Labrador Region. In particular, the results will shed light on the degree of benthic recovery associated with various lengths of fallowing, the biological processes underlying OPC dynamics in association with organic matter degradation, and the efficacy of fallowing as a mitigation strategy in the region.

AUG. 2014–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Dounia Hamoutene (DFO)

COLLABORATORS: Flora Salvo (DFO); Suzanne Dufour (MUN); Robert Sweeney (Sweeney International Marine Corp., SIMCorp Marine Environmental)

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MANAGEMENT OF HUSBANDRY PRACTICES TO MAINTAIN WATER COLUMN ENVIRONMENTAL CARRYING CAPACITY FOR BIVALVE CULTURE

Coastal regions are subject to multiple pressures (fishing, waste water discharge, agricultural run-off) and are a major provider of goods and services. Bivalve aquaculture, in addition to food production, may also yield other benefits such as the bioremediation of eutrophication symptoms due to excessive nutrient run-off. St. Peter's Bay on the north coast of Prince Edward Island (PEI), where mussel culture occupies 40% of bay area, served as a case study in this project. The goal was to investigate the combine effects of climate change, nutrient loadings and mussel aquaculture pressures. Several scenarios mixing different climatic conditions, nutrient run-off levels, and cultured mussel stocks were reproduced using a spatially explicit coupled hydrodynamic-biogeochemical. Annually, mussel meat harvesting extracts nitrogen (N) resources equivalent to 42% of river inputs or 46.5% of the net phytoplankton primary production. Under such extractive pressure, the phytoplankton biomass is being curtailed to 1980's levels when aquaculture was not yet developed and N loading was half the present level. A climate change scenario (year 2050) predicted a 30% increase in mussel production but also predicted elevated summer temperatures (>25 °C) that may have deleterious physiological effects on cultured mussels and possibly increase summer mortality levels.

This project showed the potential of mussel culture as a bioremediation tool for excessive nutrient run-off in Atlantic Canada coastal regions, which is already acknowledge in many places around the world. Results of the climate change scenario provide valuable information for adapting the management of coastal ecosystem resources and services, while these changes are occurring.

APR. 2010–MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Thomas Guyondet (DFO)

PROJECT TEAM: Luc Comeau, Rémi Sonier, Ramón Filgueira (DFO)

COLLABORATORS: Jonathan Grant (Dalhousie U); Cédric Bacher (IFREMER), Rune Rosland (U Bergen)

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COMPARING THE IMPACT OF BOTTOM AND SUSPENDED OYSTER CULTURE ON BAY-SCALE FOOD RESOURCES (FOXLEY/TROUT RIVER, PEI)

Oyster aquaculture in Prince Edward Island (PEI) is changing from traditional bottom to suspended culture methods. There are several advantages to suspending oyster stocks in the upper water column. This strategy protects stock from benthic predators and enhances growth by positioning oysters in a relatively warm and elevated food flux environment. In addition, oysters grown in suspension have a tendency to develop round shells ornamented with radial ridges and foliated processes. By contrast, oysters grown on soft, muddy bottoms tend to develop elongated and sparsely ornamented shells.

Several lease holders in the Trout River (PEI) system are seeking to convert from bottom to suspended culture. To improve the parameterization of carrying capacity models, this project evaluated whether bottom and suspended oysters compete for the same food resources within the system. Fatty acid analyses revealed that microalgae is the major (70%) dietary constituent, regardless of the culture technique. However, bottom oysters consumed more diatoms and less flagellates when compared to suspended oysters. Therefore an oyster's diet is dependent in part upon the cultivation technique.

APR. 2012–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Rémi Sonier (DFO)

PROJECT TEAM: Luc Comeau, Claudio DiBacco (DFO); Réjean Tremblay (UQAR)

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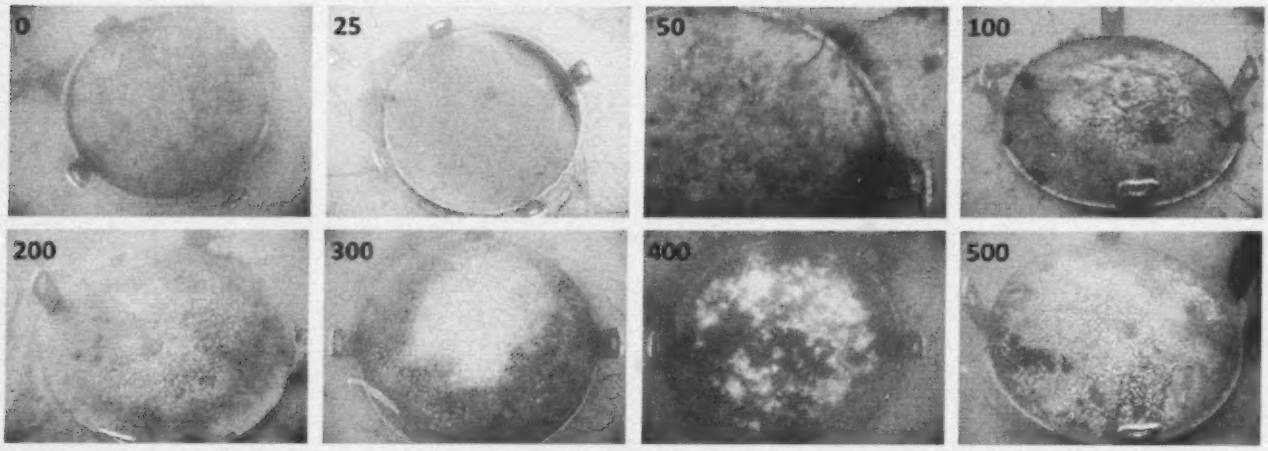
DOSE-RESPONSE RELATIONSHIPS FOR MUSSEL CULTURE AND BENTHIC CONDITIONS



Influence of increasing levels of biodeposition on benthic sediments in Îles de la Madeleine. Photo: Chris McKindsey/Andréa Weise (DFO)

Much work has shown that suspended bivalve culture has a variety of effects on benthic communities and sediment conditions due to the accumulation of biodeposits (faeces and pseudofaeces) on the seafloor in farm areas and areas immediately surrounding farms. However, dose (biodeposition rates)-response (benthic condition – in terms of benthic communities and biogeochemical indicators of these) are not well described. In this study, we evaluate dose-response relationships for mussel biodeposition and benthic conditions using manipulative experiments. In short, cages (mesocosms) were installed on the seafloor and supplemented with different levels of biodeposits. These cages allow recruitment of benthic invertebrates to occur, allowing the influence of biodeposition on benthic communities to be better understood. Benthic communities and a series of biogeochemical indicators were measured from the cages two to three months after setting up the experiments. The work was done in both Îles de la Madeleine, Quebec, and Prince Edward Island, which differ substantially in terms of background levels of eutrophication. Results from this work adds to work being done in related studies on mussel biodeposit production, modelling of biodeposits dispersal, and benthic sampling for benthic communities and sediment biogeochemical conditions in both locations. Together, these projects will allow a better prediction of bivalve culture environmental carrying capacity for the benthic environment and to better plan husbandry options to maintain a given benthic condition.

APR. 2010–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Chris McKindsey (DFO)

PROJECT TEAM: Andréa Weise (DFO); Michel Fournier (Moules de culture des Îles Inc.); Stephen Fortune (PEI Cultured Mussel Growers Association)

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BIOMASS OF THE BENTHIC INVERTEBRATE COMMUNITY AROUND FRESHWATER AQUACULTURE FARMS

The species composition of benthic invertebrates is known to change in the presence of elevated organic matter deposition generated by cage culture. However, determining the net effects of community change can be challenging, whereas biomass change can be quantified and differences presented in g/m . Benthos exposed to different deposition rates under and around farms can change from enhanced to inhibited growth and abundance. The aim of this project is to measure the benthic invertebrate biomass around farms and compared it to reference sites. Here we will present these differences at three commercial Rainbow Trout sites to understand the net effects of aquaculture on the benthic community. The results of the study will inform the current Fisheries and Oceans Canada (DFO) Fisheries Protection Program assessment of risk of freshwater finfish farms.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Cheryl Podemski (DFO)

PROJECT TEAM: Megan Otu, Jian Zhang (DFO)

COLLABORATORS: Northern Ontario Aquaculture Association; Coldwater Fisheries; Ontario Ministry of Agriculture and Food

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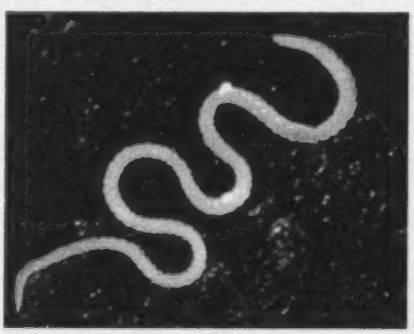

Aquatic worm (*Oligochaeta*) commonly found in freshwater lake sediments. Image taken under stereomicroscope (10X magnification)

DEVELOPMENT OF MANAGEMENT ZONES FOR FINFISH AQUACULTURE IN BRITISH COLUMBIA. PHASE 1: DATA COLLECTION AND EVALUATION. PHASE 2: INFORMATION INTEGRATION TO PROVIDE ADVICE AND RECOMMENDATIONS IN SUPPORT OF FINFISH AQUACULTURE MANAGEMENT

This project will provide science advice to enable decision makers to fully consider environmental and operations issues during the process of identifying the locations and creating the boundaries of operational plans. Issues such as farm production, disease transfer and/or control, wild-farm sea lice interactions, and others may be important components. The project's first phase is to collect, organise, and document existing scientific data, relevant to finfish aquaculture, into appropriate management zones in southern BC. The second phase of the project will apply the information gathered in Phase 1 to support the development of the interim Integrated Management of Aquaculture Plans (IMAPs). Scientific advice will be provided to help fill knowledge gaps, define ecosystem health indicators, and evaluate the local and regional impacts to determine the carrying capacity of finfish aquaculture. In addition, Phase 2 will integrate the knowledge base developed from Phase 1 with other Fisheries and Oceans Canada (DFO) research programs in BC, including the identification of ecologically and biologically significant areas, and the Strait of Georgia Ecosystem Research Initiative.

APR. 2011–MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Peter Chandler (DFO)

PROJECT TEAM: Mike Foreman, Jon Chamberlain, Roy Hourston (DFO)

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EXPLORATION OF METHODOLOGIES FOR ENVIRONMENTAL EFFECTS MONITORING OF FINFISH AQUACULTURE SITES IN SANDY BOTTOM ENVIRONMENTS WITH NATURAL DISTURBANCES: SHELBURNE, NOVA SCOTIA

The project will contribute to a better understanding of the limitations of existing methods and models and provide the basis for better informed and more extensive proposals focused on the development of survey, monitoring, and modelling approaches for this type of environment. Existing and proposed finfish sites in parts of Nova Scotia are located on sandy bottoms that experience annual disturbance by near-bottom currents generated by offshore waves. Current regulatory benthic sampling techniques (cores and light weight grabs) and models (DEPOMOD) used to monitor and predict deposition and benthic degradation have been developed for muddy bottoms. The suitability of these approaches for sandy disturbed environments is scientifically uncertain (Hargrave, 2010) and has been questioned by Nova Scotia provincial authorities and aquaculture consultants (DFO 2011 – DEPOMOD CSAS).

The purpose of this project is to test several benthic sampling approaches, including: grab samplers; Remotely Operated Vehicle (ROV) camera systems; acoustic echo sounder; side-scan sonar systems; monitoring the water current and wave environment during the anticipated disturbance season (fall-winter); analyze sediments (and acoustic signals, where appropriate) for bottom type, grain size, organic matter, and sulphide content; gather water column density profile information (i.e., CTD profiles); and run DEPOMOD scenarios for currents representing the disturbance season. As an extension to the project, sediment re-suspension and transport models will be incorporated into the FVCOM and fine-tuned for the Shelburne area.

APR. 2012–MAR. 2016

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Blythe Chang, Fred Page (DFO)

PROJECT TEAM: Mark McLean, Ed Parker, Randy Losier, Brent Law, Herb Vandermuelen, Sara Scouten, Susan Haigh, Adam Drosdowski, Vanessa Page (DFO)

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DEVELOPING HARD-BOTTOM INDICATORS FROM BRITISH COLUMBIA ARCHIVED BENTHIC VIDEO SURVEYS ASSOCIATED WITH THE AQUACULTURE ACTIVITIES REGULATIONS

The objective of this project is to apply a standard analytical approach to a large collection of archived video surveys collected as part of the British Columbia Finfish Aquaculture Waste Control Regulation (FAWCR). These video surveys were collected over a 7-year period (2004–2010) and over a wide range of coastal settings (fjordic inlets, Broughton Archipelago, the west coast of Vancouver Island, Johnstone Strait, etc.). Since the video protocols of FAWCR, recently written into the Conditions of Licence for Fisheries and Oceans Canada (DFO), are mainly based on the specifications of field survey collection, it is important to develop a video evaluation protocol for enumerating benthic organisms and identifying key indicator species. Results will determine which environmental and aquaculture factors drive the population dynamics of key primary and secondary indicator species [*Beggiatoa* spp. and Opportunistic Polychaete Complexes (OPC)], as well as how well these indicator taxa represent benthic impact through video observations and DEPOMOD predictions.

APR. 2011–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Terri Sutherland (DFO)

PROJECT TEAM: Bernie Tackema, Kerry Hoyseth, March Klaver, John Chamberlain (DFO)

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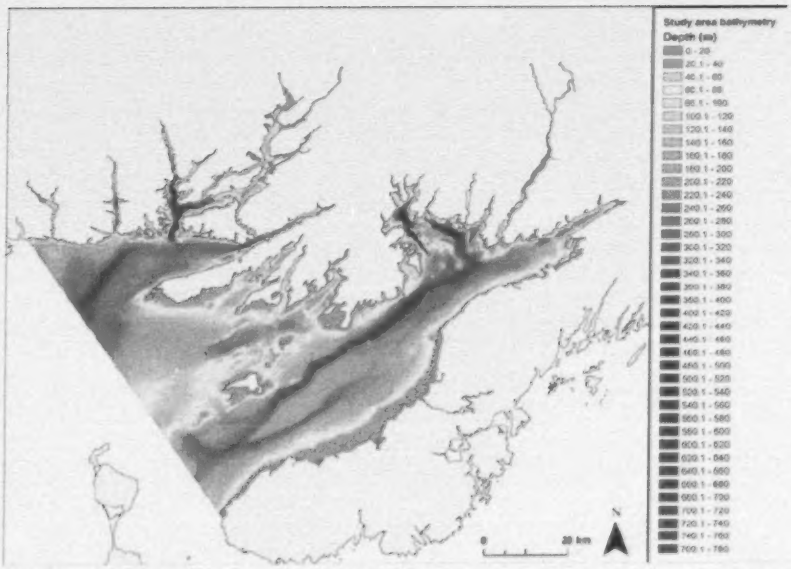
OCEANOGRAPHIC STUDY OF THE SOUTH COAST OF NEWFOUNDLAND

The expansion of aquaculture activities in new areas on the south coast of Newfoundland presents a challenge to the biosecurity and the sustainability of this growth. The objectives of this multi-year project are to understand the oceanographic conditions, including the circulation, on the South coast of Newfoundland, and provide scientifically sound information to help establish Bay Management Areas. Building on these objectives, sampling and modeling efforts were extended to Fortune Bay where cage culture has expanded and continues to grow. Sampling was conducted throughout the year (to encompass winter data) in Fortune Bay, Bay d'Espoir, Hermitage Bay, and Connaigre Bay. The results of the study will provide insight into the fundamental processes governing the ocean circulation in the area will allow for modelling and mapping of the physical environmental parameters and potential zones of influence. These zones will be used to establish production management areas to support fish health management for finfish aquaculture and support the estimation of potential environmental zones of benthic influence associated with elected finfish farms in the area.



Describing the physical oceanography of the Coast of Bays, Newfoundland, in support of aquaculture activities

APR. 2011–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Andry Ratsimandresy (DFO)

PROJECT TEAM: Danny Ings, Dwight Drover, Fred Page, Randy Losier, Mike Foreman (DFO)

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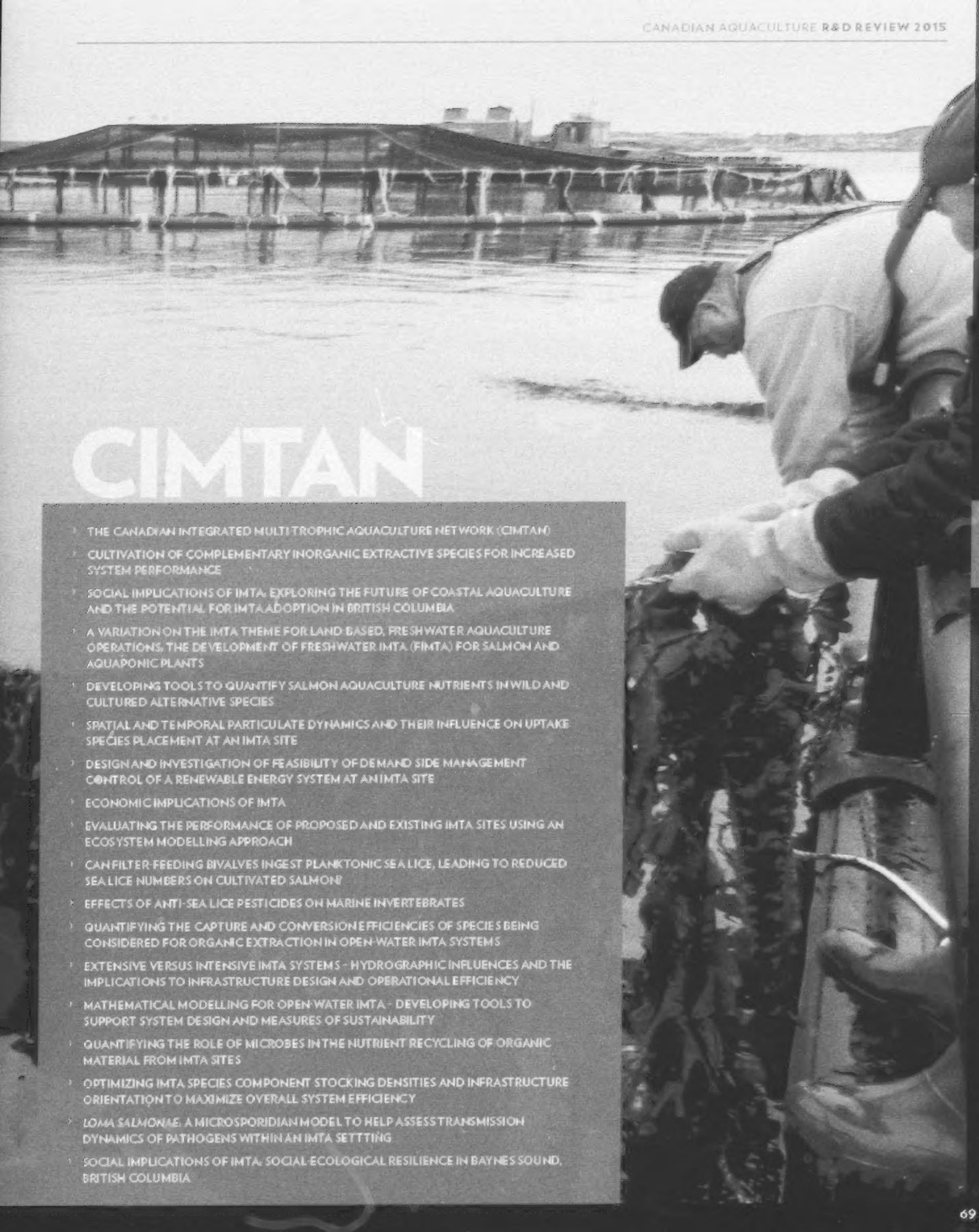
Pool's Cove, Coast of Bays region of Newfoundland. Photo: Curtis Pennell (DFO)



CIMTAN

- THE CANADIAN INTEGRATED MULTI-TROPHIC AQUACULTURE NETWORK (CIMTAN)
- CULTIVATION OF COMPLEMENTARY INORGANIC EXTRACTIVE SPECIES FOR INCREASED SYSTEM PERFORMANCE
- SOCIAL IMPLICATIONS OF IMTA: EXPLORING THE FUTURE OF COASTAL AQUACULTURE AND THE POTENTIAL FOR IMTA ADOPTION IN BRITISH COLUMBIA
- A VARIATION ON THE IMTA THEME FOR LAND-BASED, FRESHWATER AQUACULTURE OPERATIONS: THE DEVELOPMENT OF FRESHWATER IMTA (FIMTA) FOR SALMON AND AQUAPONIC PLANTS
- DEVELOPING TOOLS TO QUANTIFY SALMON AQUACULTURE NUTRIENTS IN WILD AND CULTURED ALTERNATIVE SPECIES
- SPATIAL AND TEMPORAL PARTICULATE DYNAMICS AND THEIR INFLUENCE ON UPTAKE SPECIES PLACEMENT AT AN IMTA SITE
- DESIGN AND INVESTIGATION OF FEASIBILITY OF DEMAND SIDE MANAGEMENT CONTROL OF A RENEWABLE ENERGY SYSTEM AT AN IMTA SITE
- ECONOMIC IMPLICATIONS OF IMTA
- EVALUATING THE PERFORMANCE OF PROPOSED AND EXISTING IMTA SITES USING AN ECOSYSTEM MODELLING APPROACH
- CAN FILTER-FEEDING BIVALVES INGEST PLANKTONIC SEA LICE, LEADING TO REDUCED SEA LICE NUMBERS ON CULTIVATED SALMON?
- EFFECTS OF ANTI-SEA LICE PESTICIDES ON MARINE INVERTEBRATES
- QUANTIFYING THE CAPTURE AND CONVERSION EFFICIENCIES OF SPECIES BEING CONSIDERED FOR ORGANIC EXTRACTION IN OPEN-WATER IMTA SYSTEMS
- EXTENSIVE VERSUS INTENSIVE IMTA SYSTEMS – HYDROGRAPHIC INFLUENCES AND THE IMPLICATIONS TO INFRASTRUCTURE DESIGN AND OPERATIONAL EFFICIENCY
- MATHEMATICAL MODELLING FOR OPEN-WATER IMTA – DEVELOPING TOOLS TO SUPPORT SYSTEM DESIGN AND MEASURES OF SUSTAINABILITY
- QUANTIFYING THE ROLE OF MICROBES IN THE NUTRIENT RECYCLING OF ORGANIC MATERIAL FROM IMTA SITES
- OPTIMIZING IMTA SPECIES COMPONENT STOCKING DENSITIES AND INFRASTRUCTURE ORIENTATION TO MAXIMIZE OVERALL SYSTEM EFFICIENCY
- *LOMA SALMONAE*: A MICROSPORIDIAN MODEL TO HELP ASSESS TRANSMISSION DYNAMICS OF PATHOGENS WITHIN AN IMTA SETTTING
- SOCIAL IMPLICATIONS OF IMTA: SOCIAL-ECOLOGICAL RESILIENCE IN BAYNES SOUND, BRITISH COLUMBIA

THE CANADIAN INTEGRATED MULTI-TROPHIC AQUACULTURE NETWORK (CIMTAN)

The Canadian Integrated Multi-Trophic Aquaculture Network (CIMTAN) is an NSERC strategic network initiated in 2010. It integrates academic knowledge and industrial know-how in a formal network that combines: a strategic approach; inter-disciplinary, multi-institutional and multi-sectoral strengths; and shared expertise to develop and advance innovative and improved environmentally-responsible aquaculture technologies and practices. The aim of CIMTAN research is to ecologically engineer systems for increased environmental sustainability (ecosystem services and green technologies for improved ecosystem health), economic stability (improved output, lower costs, product diversification, risk reduction, and job creation in coastal and rural communities), and societal acceptability (better management practices, improved regulatory governance, nutrient trading credit incentives, and appreciation of differentiated and safe products).

CIMTAN is providing inter-disciplinary research and development and highly qualified personnel (HQP) training in the following linked areas: (1) ecological design, ecosystem interactions, and bio-mitigative efficiency; (2) system innovation and engineering; (3) economic viability and societal acceptance; and (4) regulatory science. These areas will facilitate the commercialization of IMTA in Canada. The Network is organized into three linked Domains reflecting the four linked areas identified above: Domain 1 (environmental system performance and species interactions) is comprised of 10 projects of an environmental nature; Domain 2 (system design and engineering) is comprised of 4 projects of an engineering nature; and both are linked by the cross-cutting Domain 3 (economic analyses and social implications, with 2 projects), as biological, environmental, biotechnological, and engineering issues are always linked to economic aspects and social acceptability. Each Domain is co-led by a scientist at an academic institution and one at a Fisheries and Oceans Canada (DFO) laboratory.

The Network consists of 27 scientists from 8 universities (UBC, UNBSJ, VIU, UVic, UPEI, U Guelph, Dalhousie U, and SFU), 6 federal government laboratories (DFO), 1 provincial government laboratory (New Brunswick Research and Productivity Council), and 4 industrial partners (Cooke Aquaculture Inc., Kyuquot SEAfoods Ltd., Marine Harvest Canada Ltd., and Grieg Seafood BC Ltd.). The Network is hosted by the University of New Brunswick in Saint John (UNBSJ). Training of Highly Qualified Persons (HQPs) is a very high priority for CIMTAN. The initial target of training 114 HQPs, over the entire life of the Network, has been exceeded in 2014, as 116 have already been trained: 60 undergraduate/summer students; 22 MSc, 4 MASc, 5 MRM and 3 MA graduate students; 4 PhD students; 6 postdoctoral fellows; 11 technicians; and 1 research scientist. There has been significant mobility of HQPs and investigators within projects, between east and west coast projects and internationally (Norway and Chile), as it is important to develop a versatile and inter-disciplinary workforce if we want the scientists, policy influencers, decision makers, regulators, and industrialists of tomorrow to be innovative and build a more diversified and responsible aquaculture sector.

Photo: Thierry Chopin (UNBSJ)

One of the incremental benefits of a network approach includes access to an enlarged equipment and tool inventory at academic institutions and government laboratories. Conducting experimental research on the east and west coasts in a concerted manner allows the acquisition of complementary and compatible information, hence increasing research outputs and outcomes and reducing redundancies in research efforts. Moreover, by gathering data on a wide geographical and temporal basis, with a wide range of environmental conditions, more generalized trends may be discerned. This will allow for the design of more robust systems and policies, taking into consideration both the universality of some aspects and the regional specificity of others.

After 4 years of existence, CIMTAN has produced a diversified array of documents and media directed at different audiences: 40 refereed journal articles, 17 refereed conference publications, 8 book chapters, edited 1 Bulletin of the Aquaculture Association of Canada, 17 non-refereed publications, 198 abstracts, 2 technical reports, 1 Wikipedia article, 7 YouTube videos, 20 CIMTAN Snippets newsletters, and numerous media contacts (magazine articles, newspapers/radio/TV interviews and documentaries).

The following section describes each of the CIMTAN projects.

JAN. 2010–DEC. 2015

FUNDED BY: Natural Sciences and Engineering Research Coucil (NSERC) Strategic Network Program **CO-FUNDED BY:** Fisheries and Oceans Canada; University of New Brunswick; New Brunswick Research Productivity Council; Cooke Aquaculture Inc.; Kyuquot SEAfoods Ltd.; Marine Harvest Canada Ltd.; Grieg Seafood BC Ltd.

PROJECT LEAD: Thierry Chopin (UNBSJ)

PROJECT TEAM: Bruce MacDonald, Adrian Hamer (UNBSJ); Gregor Reid (UNBSJ/DFO); Shawn Robinson, Chris Pearce, Saleem Rahman (DFO); Maycira Costa (UVic); Duncan Knowler (SFU)

COLLABORATORS: Fisheries and Oceans Canada; The New Brunswick Research and Productivity Council; Cooke Aquaculture Inc.; Kyuquot SEAfoods Ltd.; Marine Harvest Canada Ltd.; Grieg Seafood BC Ltd.

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www.cimtan.ca

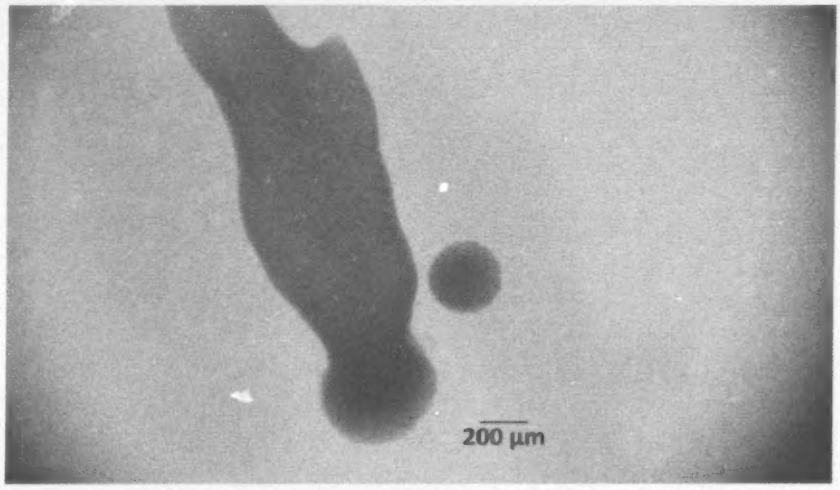
NSERC Canadian Integrated Multi-Trophic Aquaculture Network

Réseau canadien d'aquaculture multitrophique intégrée du CRSNG

CULTIVATION OF COMPLEMENTARY INORGANIC EXTRACTIVE SPECIES FOR INCREASED SYSTEM PERFORMANCE

This project investigates the red alga *Palmaria palmata* (dulse) for increased inorganic bio-mitigation of IMTA systems when kelps are not present at the sites. Little is known about the complex life history or the presence of the different phases of this species in nature, especially during fall and winter. Recruitment was monitored on the shore with twines mounted on frames. The number and size of recruits increase during summer and the occurrence of the different generations was documented. By varying desiccation time, darkness period, and seawater temperature, massive releases of tetraspores are now obtained. Desiccation and temperature play an important role in the induction of tetraspore release. A technique for rapid and reliable quantification and sizing of these large and fragile spores was developed using a Coulter Counter. We then worked on the best substrates for successful spore settlement. The effect of light on germination and growth of tetraspores into male and female gametophytes is now being studied. Molecular techniques are being developed to distinguish male gametophytes from tetrasporophytes, which are indistinguishable when reproductively immature. Organic certification was also obtained for the two kelps, *Saccharina latissima* and *Alaria esculenta*, already cultivated at the IMTA sites.

This research will develop another inorganic extractive species for the summer period, whereas kelps are at the sites from the fall to spring/early summer. The project is also looking at the development of appropriate and efficient regulations for seaweeds and for the management of inorganic nutrient biomitigation at the Bay Management Area (BMA) level.



The conundrum of the life cycle of dulse (*Palmaria palmata*): at 59 days, a female gametophyte (right) has reached its full size (less than 1 mm in diameter) and is fully reproductively mature; a juvenile male gametophyte (left) will reach its full size (10-20 cm, or more, in length) next year and will only then be reproductively mature. Given these divergent timeframes of sexual maturity, this female would have to be crossed with a male from a previous year. Photo: Constanza Chianale (UNBSJ)

JAN. 2010–DEC. 2015

FUNDED BY: Natural Sciences and Engineering Research Coucil (NSERC) Strategic Network Program **CO-FUNDED BY:** Fisheries and Oceans Canada; University of New Brunswick; New Brunswick Research Productivity Council, Cooke Aquaculture Inc.; Kyuquot SEAfoods Ltd.; Marine Harvest Canada Ltd.; Grieg Seafood BC Ltd.

PROJECT LEAD: Thierry Chopin (UNBSJ)

PROJECT TEAM: Constanza Chianale, Caroline Longtin, Ellen Belyea, Adrian Hamer, Marissa Gale (UNBSJ)

COLLABORATORS: Cooke Aquaculture Inc.

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www.cimtan.ca

SOCIAL IMPLICATIONS OF IMTA: EXPLORING THE FUTURE OF COASTAL AQUACULTURE AND THE POTENTIAL FOR IMTA ADOPTION IN BRITISH COLUMBIA

This study is identifying some of the key concerns that First Nations communities have regarding the development of aquaculture within their traditional territories. It is also assessing the level of awareness of IMTA and the information needs that must be met before First Nations can consider the adoption of IMTA.

This project focuses on the social implications (governance, community development, First Nations) aspects of IMTA. Our focus to date has been on gaining insight into First Nations perspectives on coastal aquaculture practices and their assessment of IMTA as a sustainable production system that is consistent with traditional values. This research is being undertaken on the west coast, as most aquaculture tenures in BC are located within First Nation traditional territories. Any changes in existing tenures, or development of new ones, require consultation with First Nations communities. To provide a basis for broader consultations regarding the opportunities and challenges facing the adoption of IMTA within First Nations traditional territories, a key informant survey was undertaken to assess concerns with seaweed, shellfish, and finfish farming. Generally, farming seaweeds was not something that had been considered by the communities. Shellfish aquaculture, however, was seen as a promising economic development opportunity that was consistent with their traditional values. There was very strong opposition to salmon farming owing to the perceived environmental and ecosystem impacts. While there was interest in IMTA, the informants also acknowledged a lack of information on the ecological and economic aspects of its development.

JAN. 2010–DEC. 2015

FUNDED BY: Natural Sciences and Engineering Research Coucil (NSERC) Strategic Network Program **CO-FUNDED BY:** Fisheries and Oceans Canada (DFO); University of New Brunswick; New Brunswick Research Productivity Council; Cooke Aquaculture Inc.; Kyuquot SEAfoods Ltd.; Marine Harvest Canada Ltd.; Grieg Seafood BC Ltd.

PROJECT LEAD: Mark Flaherty (UVic)

PROJECT TEAM: Grant Murray (VIU); Stephen Cross, Erin Latham, Katie Tubbutt (UVic)

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A VARIATION ON THE IMTA THEME FOR LAND-BASED, FRESHWATER AQUACULTURE OPERATIONS: THE DEVELOPMENT OF FRESHWATER IMTA (FIMTA) FOR SALMON AND AQUAPONIC PLANTS

The Freshwater IMTA program (FIMTA) helps identify effluent treatment efficiency strategies for different hatchery configurations to meet regulatory limits. The pilot-scale FIMTA system is very useful for selecting plants that will be a good match for conditions experienced at fish hatcheries in a cold temperate climate. Developing FIMTA will allow an extension of IMTA from egg to plate, increase water reuse, and product diversification.

Analyses were performed to identify the best setting for a pilot FIMTA project at different freshwater salmon hatchery facilities. A computerized visual assessment tool was developed to evaluate hatchery performances regarding dissolved nutrient recovery. The treatment system efficacy (physical, chemical, and biological) was analysed at different locations within hatcheries. A visual interface provides a fast and reliable way to simplify application development and accelerate management. Data are then subjected to regulatory levels. The program contains a series of databases accessible to the various software objects, including both static and dynamic data. Databases are maintained for each component for basic information, simulation settings, and water characteristics. The program consists of a communication interface and other basic forms such as necessary flow, nutrient concentrations, and efficiency potential percentages. The management tool interface can identify and predict dissolved nutrient concentrations and flows at the different locations. A variety of edible, ornamental, and medicinal plants are tested for growth and nutrient absorption capabilities in a temperature/light controlled FIMTA pilot-scale system using effluent water from a local commercial hatchery. The use of IMTA kelp biochar, as a medium for seedling development and plant support, is also examined.

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Hamid Khoda Bakhsh, Stacy Murray, and Thierry Chopin contemplating their first FIMTA production. Time to prepare the salad dressing! Photo: Adrian Hamer (UNBSJ)

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DEVELOPING TOOLS TO QUANTIFY SALMON AQUACULTURE NUTRIENTS IN WILD AND CULTURED ALTERNATIVE SPECIES

New methods to quantify and monitor impacts of aquaculture nutrient enrichment on the environment are being investigated. To better understand the influence of particulate nutrient sources in the midwater zone, the relationship between fouling species, distance, and the physical environment were tested using an array of bio-colonization plates. The most prevalent fouling species near salmon aquaculture sites are studied for changes in bio-accumulation rates and instantaneous growth. Bio-accumulation for these species is surprisingly variable around a salmon farm and can provide information on optimal IMTA site design with respect to nutrient availability and environmental conditions. The colour response in three native macro-algae (*Ulva lactuca*, *Pyropia purpurea*, and *Palmaria palmata*), relative to their total nitrogen content, has also been investigated. The objective is to develop a simple technique, based on colour characterization (lightness, chroma, and hue), as a faster and cheaper proxy for biochemical analyses of tissue total nitrogen content. If this approach can lead to the development of a useful tool, monitors will be able to quickly and cheaply determine the internal nitrogen content of the selected algal species and the conditions to which it was likely to have been exposed, using this macro-alga as an indicator-over-time of nutrient loading.

Such methods can offer new tools for measuring changes in nutrient exposure for both wild and cultured species in the coastal zone, and a new approach to monitoring nutrient effects of aquaculture with respect to optimal design for integrated species and overall site performance.

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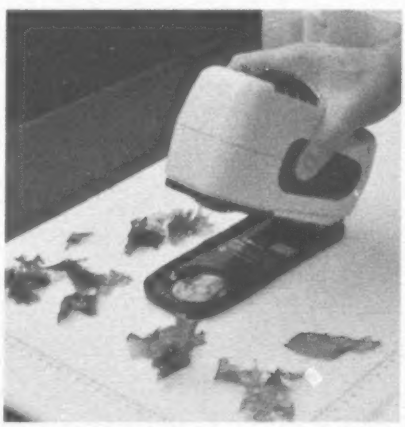
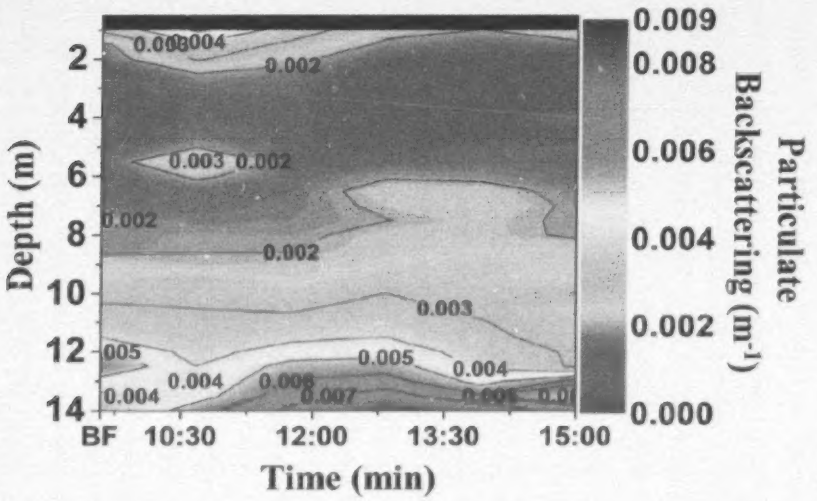


Fragments of the green alga, *Ulva lactuca*, analyzed for their colour with a handheld colour spectrometer as a means of monitoring dissolved nutrients. Photo: Andrew Cooper (DFO)

SPATIAL AND TEMPORAL PARTICULATE DYNAMICS AND THEIR INFLUENCE ON UPTAKE SPECIES PLACEMENT AT AN IMTA SITE



Plot of particulate backscattering (colour mapping), which is a proxy for particulate concentrations, with depth (y-axis) and time through the day (x-axis). Take note of the higher values at the bottom of the cage (14 m), which increase directly after the fish were fed (approximately at 10:30).

This research shows the value of using high resolution bio-optical data within an IMTA setting. The results are consistent with others showing particulate waste dilution during high ambient seston periods and the dominant vertical dispersion of particulate wastes towards the seafloor.

Bio-optical parameters are commonly used to collect high resolution particulate concentration/composition data within the coastal environment. However, these methods are rarely utilized within aquaculture settings. This study focused on the collection of bio-optical data within a sablefish cage at an IMTA site on the west coast of Vancouver Island. This was done to gain an understanding of ambient particulate dynamics and also to detail the dispersion of organic wastes to aid in the placement of secondary uptake species for waste assimilation. During autumn/winter, ambient seston concentrations were low and distinct bio-optical enhancements were measured with time after feeding at the bottom of the studied cage, likely due to fish wastes. In contrast, spring/summer bio-optical variability was driven by phytoplankton and wastes were likely diluted into the particle rich environments. These results suggest that particulate wastes would be most available to uptake species during low seston conditions. Additionally, due to the observed dominant vertical movement of wastes, the most effective placement of uptake species for waste assimilation is likely below the studied cage. With further research, bio-optical measurements could provide valuable high resolution data on both ambient and waste particulate dynamics within aquaculture settings.

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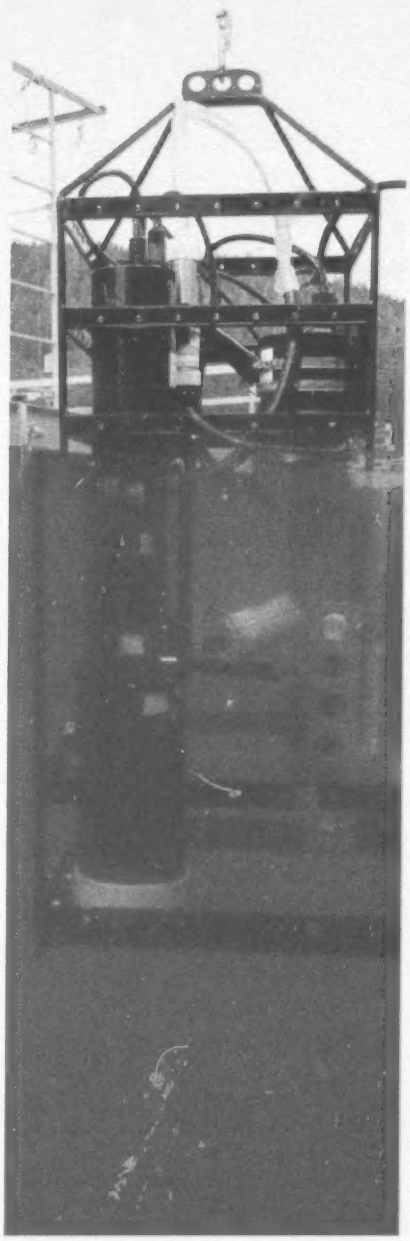

The bio-optical profiler being lowered into a Sablefish cage. Photo: Justin Del Bel Belluz (UVic)

DESIGN AND INVESTIGATION OF FEASIBILITY OF DEMAND SIDE MANAGEMENT CONTROL OF A RENEWABLE ENERGY SYSTEM AT AN IMTA SITE

Aquaculture sites are often remotely located, far from grid electricity. As the overall intent of IMTA is to reduce the environmental impact of aquaculture operations, the provision of clean power on-site is being investigated to avoid the need for diesel gensets which are used currently. The primary electrical loads are a set of winches on a moveable tram used for raising and lowering extractive species nets. A battery-solar system has been initially designed for the west coast demonstration site using a custom probabilistic energy system sizing program. Detailed physical design of the system has evolved to a configuration that places the solar panels and battery modules in a hut at one end of the fish farm docks, and includes a diesel backup to ensure continuous operations in the event of system interruption. The system consists of eight 175 W solar panels, a 1500 Ah battery bank, and an existing 2 kW backup gasoline generator. Cables then provide power to the mobile tram with electric winches, as well as various power ports on the docks for incidental loads. Sensors are included to measure system performance and insolation (exposure to the sun) for testing purposes. Once the system is fully installed and operational, data will be gathered to assess the accuracy of the prediction/sizing models, thereby validating the model for use in the design of renewable energy systems for other IMTA sites.

General layout of the 2.2 kW renewable energy system to power the SEATram at Kyuquot SEAFoods Ltd. This solar photo-voltaic system will provide clean energy throughout the year, reducing farm greenhouse gas (GHG) emissions and improving shellfish grading and harvesting operations. Photo: Stephen Cross (UVic)

The demonstation project will prove out the feasibility of a renewably powered IMTA system on the west coast. The sizing/performance modelling tool will be validated and available for future design of other IMTA renewable systems.

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ECONOMIC IMPLICATIONS OF IMTA

In the last year, we completed a first ever assessment of how British Columbians value their coastal environment as a pretext to examining the role that IMTA might play in supporting these values. Since we carried out similar analyses in the markets for BC farmed salmon earlier (in the USA), we anticipate an interesting comparative analysis to emerge from this work. Similarly, we framed our research in both locations to be a comparison of IMTA and closed containment versus conventional monoculture, so that we could assess preferences for these two alternative technologies in relation to the monoculture reference. Our initial results suggest that US consumers view IMTA much more favorably than closed containment, while BC residents are the opposite. Thus, we detect large differences in preferences between the producing (BC) and consuming (USA west coast) regions towards alternative technologies. This year also saw our newly initiated research emphasis shift from the market context for IMTA to modelling the production economics side of IMTA, including qualitative analyses of the industry's reasons for adoption or non-adoption, identifying the full costs of shifting to IMTA, and simulating the full economic and environmental costs of IMTA versus monoculture. Results are not yet available for these activities.

We anticipate our main impact will be on how policymakers, researchers, and the general public perceive the appropriate response to problems associated with monoculture salmon farming. Our expectation is that this will influence the design of incentives to help the industry better align its activities with society's best interests and to allow IMTA to play an appropriate role in the process.

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EVALUATING THE PERFORMANCE OF PROPOSED AND EXISTING IMTA SITES USING AN ECOSYSTEM MODELLING APPROACH

This modelling scheme provides valuable information for the aquaculture industry in order to improve the siting of existing and new IMTA sites. The outcomes of the model could be used to define areas of potential impact, investigate interactions with other marine resources, and design monitoring guidelines.

The design of ocean-based finfish-shellfish IMTA farms is not trivial due to the complexity of coastal areas, particularly because biological processes in open-waters are influenced by water circulation, which includes the dispersal of finfish wastes. Consequently, the design of new IMTA sites or the evaluation of existing sites require a combined study of biological and physical processes, which can be achieved by the execution and coupling of mathematical models. In this project, a highly configurable mathematical model that can be applied at the apparent spatial scale of IMTA sites has been developed. The model allows for tracking of the different components of the seston in an IMTA site, including feed wastes, fish faeces, shellfish faeces, natural detritus, and phytoplankton. Based on the characterization of these fluxes of matter, the model can be used to explore different spatial arrangements for evaluating and improving finfish/shellfish farm efficiency. The model also predicts that the mitigation efficiency of the IMTA farm is highly dependent on the background environmental conditions.

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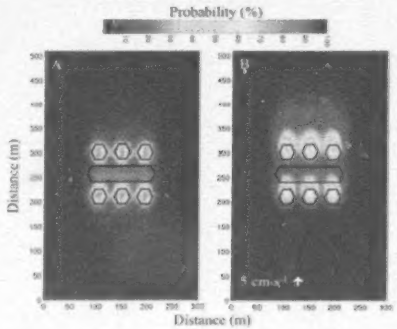

Mapping at a theoretical IMTA site. Regular hexagons represent fish cages and the irregular ones shellfish long-lines. A) Probability map of vertical flux of carbon distribution at 15 m depth (beneath fish cages) over a tidal cycle. B) Probability map of fish faeces distribution in the water column when velocity peaks at 5 cm/s in the direction of the arrow. Image: Ramón Filgueira (DFO)

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CAN FILTER-FEEDING BIVALVES INGEST PLANKTONIC SEA LICE, LEADING TO REDUCED SEA LICE NUMBERS ON CULTIVATED SALMON?

The development of non-chemical sea lice mitigation techniques such as IMTA filter-feeding bivalves may help improve the environmental, societal, and economic performance of salmon farms.

The close proximity of salmon farms and wild Pacific salmon stocks in British Columbia is an important incentive for precautionary sea lice management strategies. We are investigating whether IMTA filter-feeding bivalves can provide preventative, natural sea louse control by ingesting sea lice larvae (nauplii and copepodids) from the water column, a system that exploits the sea louse life cycle and the natural filtration capabilities of bivalves. Field trials were conducted at a commercial salmon farm in British Columbia using Pacific Oysters, one of several bivalve species that consumed sea lice larvae in previous laboratory experiments. 30,000 oysters were deployed in trays at three depths around one end of the farm's 2 x 7 square-cage array, and at a nearby control site. Throughout the study, oysters at the farm generally grew larger (both in shell length and tissue biomass) than oysters at the control site. Larval and attached sea lice stages were counted monthly in bivalve and control (no bivalves) fish cages. Sea lice larval densities and numbers of sea lice on the fish followed a similar monthly trend, peaking in January/February. Oyster digestive tracts were preserved and will be analyzed for partially-digested sea lice and sea louse DNA presence.

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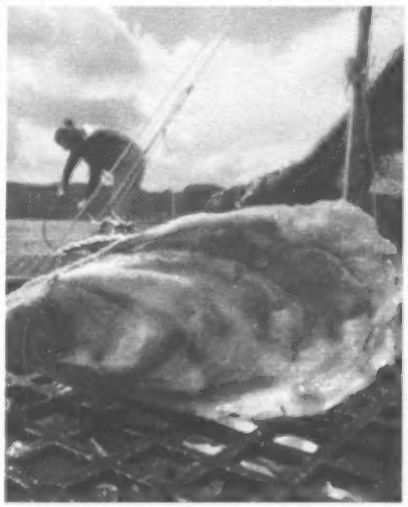

Cleaning biofouling from Pacific Oyster trays at a salmon farm in the Broughton Archipelago, British Columbia. Photo: Allison Byrne (UVic)

EFFECTS OF ANTI-SEA LICE PESTICIDES ON MARINE INVERTEBRATES

Pesticides used to control ectoparasitic sea lice in salmon aquaculture are released in effluent plumes or treated feed and faeces from cage sites and have the potential to adversely affect non-target organisms. The toxicity of common anti-sea lice treatments AlphaMax® (active ingredient (a.i.) deltamethrin), Excis® (a.i. cypermethrin), Interox®Paramove™ 50 (a.i. hydrogen peroxide), Salmosan® (a.i. azamethiphos), and emamectin benzoate (an avermectin) have not been adequately studied for benthic crustaceans, such as marine amphipods, clam worms (sediment dwellers), and zooplankton living in the water column. The main objectives were to examine whether several species of invertebrates, native to the Bay of Fundy, are affected by common anti-sea lice treatments. Growth, behaviour, and survival of clam worms, zooplankton, and amphipods were assessed after shorter-term (up to 96 hours) and longer-term (10 to 30 days) exposures. Emamectin benzoate and AlphaMax® decreased the growth and burrowing behaviour of clam worms at sediment concentrations that may be found near cage sites. Similarly, environmentally realistic exposures of zooplankton to several of the pesticides reduced feeding and survival. Amphipod survival also decreased at AlphaMax® and Excis® concentrations that may be found in an effluent plume from a cage site.

Sea worms (*Nereis virens*) being placed in freshly prepared emamectin benzoate-spiked beakers for exposure during a 30-day serial replacement bioassay. Photo: Geoff McBriarty (UNBSJ)

These results suggest that the use of some anti-sea lice pesticides may pose a risk to non-target marine invertebrates living in the sediments and water column near cage sites.

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QUANTIFYING THE CAPTURE AND CONVERSION EFFICIENCIES OF SPECIES BEING CONSIDERED FOR ORGANIC EXTRACTION IN OPEN-WATER IMTA SYSTEMS

This project is assessing the capability of different invertebrate species to capture, absorb and convert particulate fish-farm waste into new production. On the east coast, Blue Mussels (*Mytilus edulis*) have been shown to be capable of ingesting and efficiently absorbing small organic material from both fish food, and faeces. After a variety of feeding trials using small artificial diets in the laboratory and natural particles at IMTA sites, we determined that the Orange-footed Sea Cucumber (*Cucumaria frondosa*) could also efficiently extract larger organic material from farm waste. Ongoing studies include assessing the feeding rate and particle size that sea cucumbers are utilizing as well as their faecal deposition rates. On the west coast, species being assessed for extractive capabilities include filter feeders, such as Basket Cockles (*Clinocardium nuttallii*) and *M. edulis*, as well as deposit feeders such as Green Sea Urchins (*Strongylocentrotus droebachiensis*), California Sea Cucumbers (*Parastichopus californicus*) and Pacific Prawns (*Pandalus platyceros*). Sea urchins and sea cucumbers were found to ingest and absorb Sablefish (*Anoplopoma fimbria*) faeces at rates comparable to or higher than those for traditional diets such as kelps and natural sediment, respectively.

This research has enabled the assessment of nutritional responses for a variety of shellfish and deposit-feeder species on diets of fish-farm organics, thereby providing crucial insight into co-cultured species selection and IMTA system efficiency.

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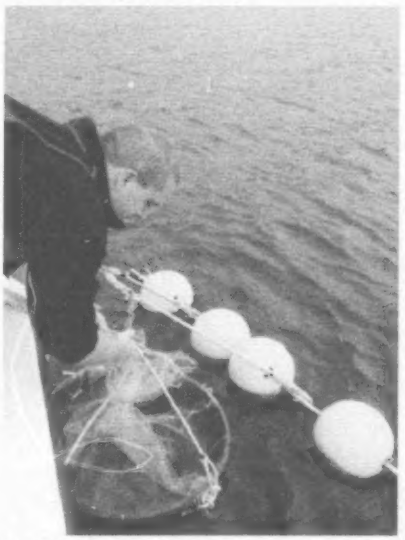


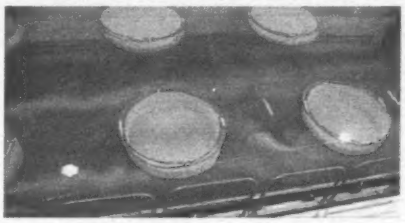
Kurt Simmons (UNBSJ) placing sea cucumbers in a sediment collector to estimate deposition rates in the field. Photo: Taryn Minch (UNBSJ)

EXTENSIVE VERSUS INTENSIVE IMTA SYSTEMS–HYDROGRAPHIC INFLUENCES AND THE IMPLICATIONS TO INFRASTRUCTURE DESIGN AND OPERATIONAL EFFICIENCY

This project aims to quantify near and far-field hydrodynamics of square and circular cage arrays to guide in the placement of co-cultured species. Initial project work utilized the Finite-Volume primitive equation Community Ocean Model (FVCOM) to model localized currents around an IMTA site in Kyuquot Sound, Vancouver Island. Recent project developments have involved the deployment of 1 to 15 scale model cage-arrays in the Flume Tank facility at Memorial University of Newfoundland. Wake velocity studies have been completed on east coast circular aquaculture cage-arrays at common cage spacing used in the industry. Measurements at different distances downstream of the model arrays show wake topology, velocity deficits, and wake recovery. Unsteadiness and large scale turbulence has been observed in the wake of cage-arrays.

Dye release studies have been completed in order to observe the flow field in and around cages within the array. Results to date indicate large velocity deficits in cages wakes, forcing flow around and below cages. The dye release data agree well with wake velocity measurements.

This research has led to a better understanding of fish cage-array effects on hydrodynamics and how this can influence near-field nutrient delivery from fish to co-cultured species.



Dye release study with 1 to 15 scale model cage-array, at the Flume Tank facility of Memorial University of Newfoundland. Photo: Adam Turner (UNBF)

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MATHEMATICAL MODELLING FOR OPEN-WATER IMTA–DEVELOPING TOOLS TO SUPPORT SYSTEM DESIGN AND MEASURES OF SUSTAINABILITY

This project aims to quantify open-water IMTA efficiency of nutrient recovery and augmented growth. Several publications have been produced to date. One study explored the seaweed biomass required to remove soluble nutrients from salmon culture. The mean weight ratios of the seaweeds *Alaria esculenta* and *Saccharina latissima* required to sequester all soluble nutrients excreted per unit weight of salmon range from 4:1 to 13:1, depending on the nutrient. Another study reported the proportion of fish farm solids ingested by mussels needed to reduce site-wide organic loading at an IMTA site, which ranged between 10% and 20%. A third modelling study suggested the bio-mitigation potential of mussels will be greatest where seston abundance is low, organic dietary content high, and that achieving maximal waste extraction by mussel co-culture entails food particule depletion that may limit mussel production. Organic mitigation efficiency of deposit feeders are presently being modelled. Project results are providing valuable inputs for an IMTA bio-economic model being developed. This project has recently fostered some unique collaborations with IMTA projects in Norway.

This work has led to a better understanding of overall system efficiencies and has guided in the effective development of open-water IMTA farms, through such mechanisms as the Canadian Science Advisory Secretariat review process to support policy development and management for Fisheries and Oceans Canada.

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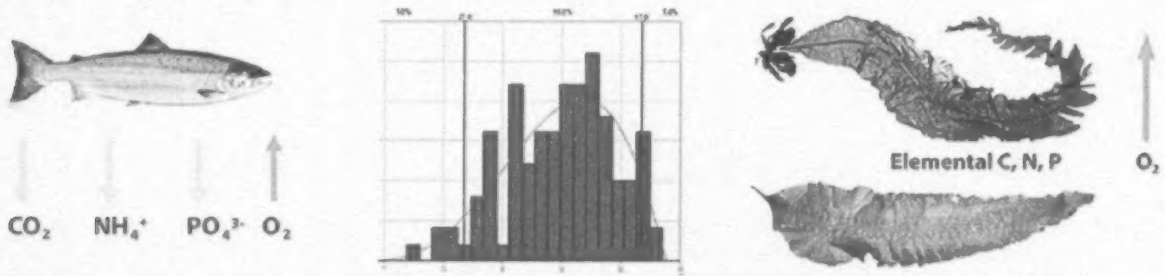

Schematic representation of model elements to estimate weight ratios of seaweeds needed to sequester nutrients from salmon. Image: Gregor Reid, Thierry Chopin (UNBSJ)

QUANTIFYING THE ROLE OF MICROBES IN THE NUTRIENT RECYCLING OF ORGANIC MATERIAL FROM IMTA SITES

Craig Smith (DFO, left) helping Hannah Bradford (UNBSJ, right) to collect seawater samples to measure bacterial densities from the water column around a salmon farm. Photo: Shawn Robinson (DFO)

Understanding how nutrients are recycled around aquaculture sites in both time and space will allow better designing of future fish farms and how to fallow them between crops.

Marine bacteria are ubiquitous in both pelagic and benthic environments where they play a significant role in biomass, biodiversity, and biogeochemical processes such as recycling of organic nutrients. Most are nonpathogenic, generally operate unseen due to their small size, but are thought to be important in the nutrient dynamics around aquaculture farms. The objectives of this project are to determine bacterial species composition and abundance and their ecological role in nutrient recycling at IMTA sites. The research is showing that there are significant differences in the patterns of nutrient dynamics occurring in the water column compared to the sea bottom. Gradients of dissolved and particulate nutrients are very difficult to detect in the water column although higher levels of bacteria can be found near the farm, suggesting that these bacteria are capable of quickly assimilating the released nutrients. On the sea bottom near the farm where most of the particulate matter settles, there is a decreasing gradient of bacteria away from the site. Based on molecular analytical techniques, the study is finding that the bacterial species closest to the site are often specialists in nutrient recycling. This information is being incorporated into a computer model on nutrient dynamics at IMTA sites.

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OPTIMIZING IMTA SPECIES COMPONENT STOCKING DENSITIES AND INFRASTRUCTURE ORIENTATION TO MAXIMIZE OVERALL SYSTEM EFFICIENCY

Expanding our knowledge of nutrient transfer within current IMTA site designs will help the industry develop their infrastructure. Developing the aquaculture of the California Sea Cucumber (*Parastichopus californicus*), as a benthic extractive species within IMTA systems, and addressing issues such as its containment, will be mutually beneficial to resource managers and industry partners.

To improve the sustainability of IMTA systems, extractive species' stocking densities and infrastructure orientations need to be optimised such that they maximise the interception of fish-farm nutrients and IMTA efficiency. In order to achieve this objective, the dynamics of nutrient transfer within the site needs to be understood to choose the best configuration and species mix. On the east coast, empirical studies on flow patterns, organic particle densities, and their utilization by farmed and wild species are studied on conventional salmon and IMTA sites to provide input on a model for site efficiency. On the west coast, the project is focused on optimizing the benthic extraction of nutrients within an IMTA system using the detritus-feeding California Sea Cucumber, *P. californicus*. The California Sea Cucumber has been established as a promising candidate for IMTA due to its ability to extract benthic nutrients and its high market value. The potential for suspended trays within an IMTA system, as juvenile rearing habitat for *P. californicus*, are further examined. A suspended-tray design is being investigated in order to optimize nutrient delivery, water quality, and stocking density, while decreasing bio-fouling and addressing containment issues of juvenile *P. californicus*.

JAN. 2013–DEC. 2015

FUNDED BY: Natural Sciences and Engineering Research Coucil (NSERC) Strategic Network Program **CO-FUNDED BY:** Fisheries and Oceans Canada (DFO); University of New Brunswick; New Brunswick Research Productivity Council; Cooke Aquaculture Inc.; Kyuquot SEAfoods Ltd.; Marine Harvest Canada Ltd.; Grieg Seafood BC Ltd.

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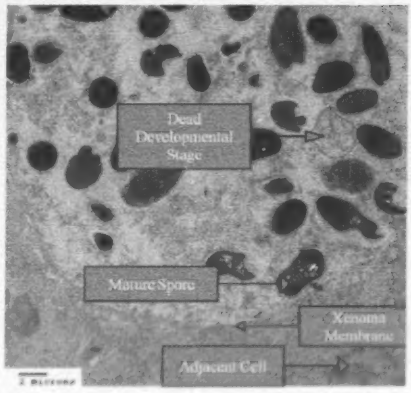
Juvenile California Sea Cucumber, *Parastichopus californicus*, found within suspended shellfish aquaculture on the west coast of British Columbia. Photo: Angela Fortune (UVic)

LOMA SALMONAE: A MICROSPORIDIAN MODEL TO HELP ASSESS TRANSMISSION DYNAMICS OF PATHOGENS WITHIN AN IMTA SETTTING

The introduction of a bivalve component alongside a salmon growing operation may provide beneficial disease reduction services. A greater understanding of disease dynamics between trophic levels is a key part of health management within integrated settings.

Our goal has been to modify an infection model for the microsporidian pathogen *Loma salmonae*, and use this model to evaluate the role that Blue Mussels may have to act as environmentally released spores within an IMTA setting. Specifically, asking the question of whether Blue Mussels may serve to mitigate disease transmission by deactivating spores that they encounter during feeding. The model has been successfully developed and now allows us to modify various environmental and temporal parameters. A very useful, and unexpected outcome, was the establishment of *L. salmonae* within cell culture. This advance will allow far greater flexibility in our studies, both as a tool for producing spores, but also for detecting them within environmental niches under study. To date, we have determined that Blue Mussels are very effective in extracting microsporidial spores from the environmnent; spores are subsequently released in pseudofeces, or feces, and small proportion of them stored for several weeks within mussel viscera. Spores are not rendered defective whether they are retained, or passed within egesta; *in vitro* tests of spore viability have been evaluated against the gold standard *in vivo* measures of infectivity.



Microsporidial spores developing within a cell-cultured xenoma. Photo: Sarah McConnachie (UPEI-AVC)

JAN. 2010–DEC. 2015

FUNDED BY: Natural Sciences and Engineering Research Coucil (NSERC) Strategic Network Program **CO-FUNDED BY:** Fisheries and Oceans Canada (DFO); University of New Brunswick; New Brunswick Research Productivity Council; Cooke Aquaculture Inc.; Kyuquot SEAfoods Ltd.; Marine Harvest Canada Ltd.; Grieg Seafood BC Ltd.

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SOCIAL IMPLICATIONS OF IMTA: SOCIAL-ECOLOGICAL RESILIENCE IN BAYNES SOUND, BRITISH COLUMBIA

When asked to weigh the costs and benefits of the industry, most participants expressed uncertainty. This uncertainty may indicate ongoing struggles to balance what many feel are largely economic benefits against experiential and environmental concerns. It may also signal that participants have not yet fully formed a solidly positive or negative opinion of the industry, offering an opportunity to the shellfish industry.

As a relatively new industry, it is unclear how aquaculture affects the well-being of the social-ecological systems in which it is embedded. Baynes Sound farms produce half of all shellfish cultured in British Columbia, over 3,700 tonnes per year, and are surrounded by more than 6,500 residents on Vancouver Island and Denman Island. To ensure the ecological, economic, and social sustainability of Baynes Sound, and other social-ecological systems, the aquaculture industry must be better understood. The concept of well-being helps us move beyond simple "jobs versus the environment" understandings of effects, and provides a more holistic way to understand the preferences the residences of Baynes Sound have for social-ecological conditions and the ways in which these conditions may be enhanced or diminished by shellfish aquaculture activities.

View of Baynes Sound, British Columbia. Photo: Brian Kingzett (VIU)

The purpose of this research study was to identify and measure the perceived effects of shellfish aquaculture on the Baynes Sound social-ecological system. Over a three year period, we used qualitative interviews, surveys, focus groups, and a photo-voice component to answer the question: what are the mechanisms by which the activities of the shellfish aquaculture industry promote and/or erode community well-being in the Baynes Sound social-ecological system as assessed by local residents?

JAN. 2010–DEC. 2015

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC) Strategic Network Program

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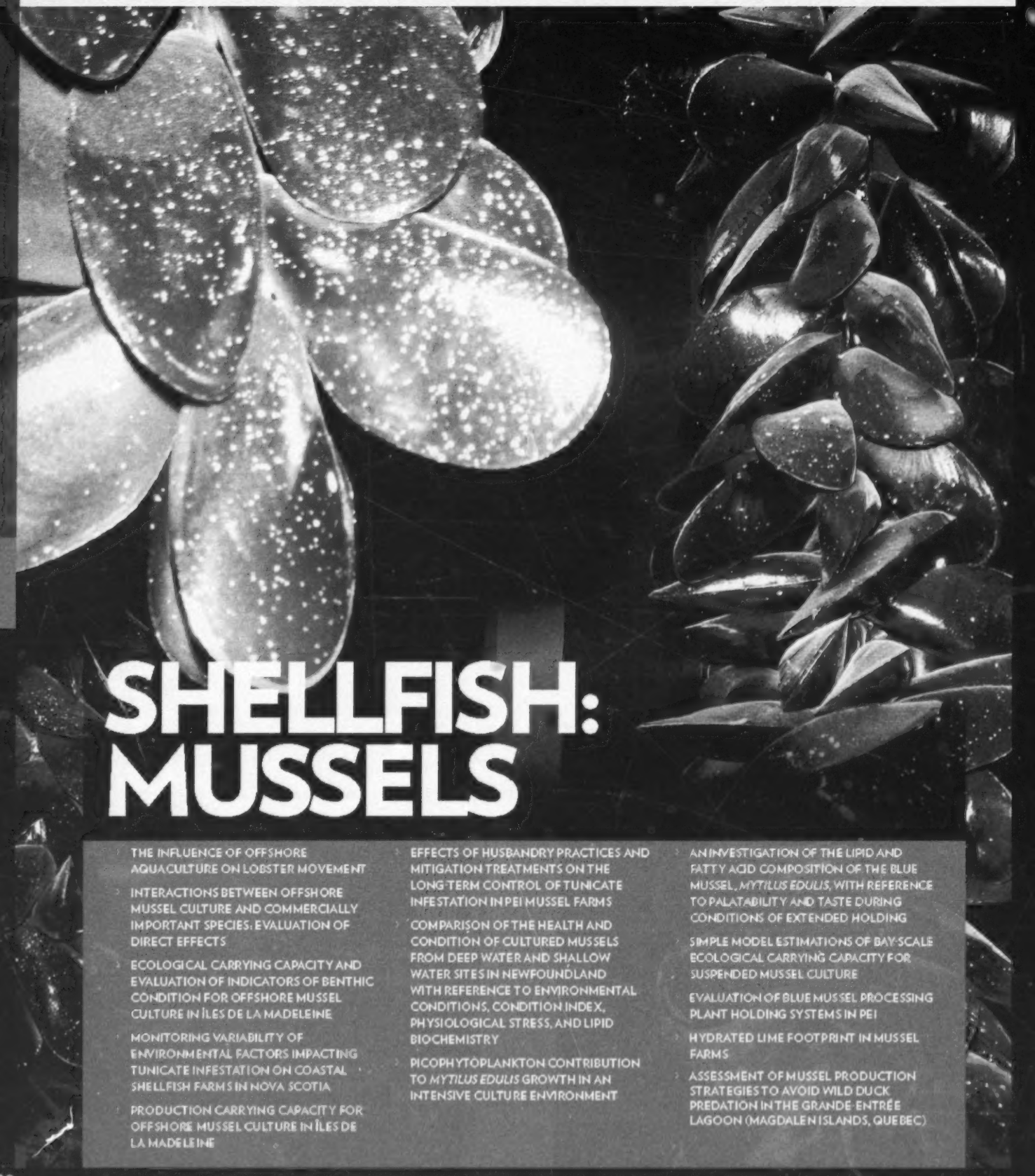

SHELLFISH: MUSSELS

- THE INFLUENCE OF OFFSHORE AQUACULTURE ON LOBSTER MOVEMENT
- INTERACTIONS BETWEEN OFFSHORE MUSSEL CULTURE AND COMMERCIALLY IMPORTANT SPECIES: EVALUATION OF DIRECT EFFECTS
- ECOLOGICAL CARRYING CAPACITY AND EVALUATION OF INDICATORS OF BENTHIC CONDITION FOR OFFSHORE MUSSEL CULTURE IN ÎLES DE LA MADELEINE
- MONITORING VARIABILITY OF ENVIRONMENTAL FACTORS IMPACTING TUNICATE INFESTATION ON COASTAL SHELLFISH FARMS IN NOVA SCOTIA
- PRODUCTION CARRYING CAPACITY FOR OFFSHORE MUSSEL CULTURE IN ÎLES DE LA MADELEINE
- EFFECTS OF HUSBANDRY PRACTICES AND MITIGATION TREATMENTS ON THE LONG-TERM CONTROL OF TUNICATE INFESTATION IN PEI MUSSEL FARMS
- COMPARISON OF THE HEALTH AND CONDITION OF CULTURED MUSSELS FROM DEEP WATER AND SHALLOW WATER SITES IN NEWFOUNDLAND WITH REFERENCE TO ENVIRONMENTAL CONDITIONS, CONDITION INDEX, PHYSIOLOGICAL STRESS, AND LIPID BIOCHEMISTRY
- PICOPHYTOPLANKTON CONTRIBUTION TO *MYTILUS EDULIS* GROWTH IN AN INTENSIVE CULTURE ENVIRONMENT
- AN INVESTIGATION OF THE LIPID AND FATTY ACID COMPOSITION OF THE BLUE MUSSEL, *MYTILUS EDULIS*, WITH REFERENCE TO PALATABILITY AND TASTE DURING CONDITIONS OF EXTENDED HOLDING
- SIMPLE MODEL ESTIMATIONS OF BAY-SCALE ECOLOGICAL CARRYING CAPACITY FOR SUSPENDED MUSSEL CULTURE
- EVALUATION OF BLUE MUSSEL PROCESSING PLANT HOLDING SYSTEMS IN PEI
- HYDRATED LIME FOOTPRINT IN MUSSEL FARMS
- ASSESSMENT OF MUSSEL PRODUCTION STRATEGIES TO AVOID WILD DUCK PREDATION IN THE GRANDE-ENTRÉE LAGOON (MAGDALEN ISLANDS, QUEBEC)

THE INFLUENCE OF OFFSHORE AQUACULTURE ON LOBSTER MOVEMENT

MSc. student, Émilie Simard, tags lobsters with acoustic transmitters to follow their movements within and around a mussel farm offshore of Îles de la Madeleine. Photo: Chris McKindsey (DFO)

Mussel aquaculture acts to aggregate lobster due to the provision of physical structure (anchor blocks) and food resources (mussel fall-off from culture structures and aggregation of crabs, which are the major prey of lobster). It has been hypothesized that lobster, once they happen upon a mussel farm, will not leave the area as some of their basic needs (i.e., habitat structure and food) are more abundant in these locations than others, particularly in areas with unstructured (i.e., sandy or muddy) bottoms, as is the case in offshore mussel farm locations in Îles de la Madeleine, Quebec. In this study, acoustic methods are being used to determine the affinity of lobster to a mussel culture site in Îles de la Madeleine. In short, 15 lobsters found within the culture site and 15 lobsters found in each of 2 areas outside of the culture site were fitted with acoustic transmitters, and placed back to where they were captured. Another 15 lobster were caught outside of the mussel farm, fitted with acoustic transmitters, and placed within the farm site. Lobster movements were followed within 3 arrays of 10 fixed receivers within, and in the two experimental areas established adjacent to, the farm site. After 2 months, receivers were recovered and lobster movements determined from recorded signals. The results of this work will increase our knowledge of the interactions between cultured bivalves and a commercially important species, and thus aid in the decision process for new lease sites.

APR. 2013–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** La Société de développement de l'industrie maricole (SODIM); Ressources Aquatiques Québec (RAQ); Université du Québec à Rimouski (UQAR)

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INTERACTIONS BETWEEN OFFSHORE MUSSEL CULTURE AND COMMERCIALLY IMPORTANT SPECIES: EVALUATION OF DIRECT EFFECTS

In enclosed embayments, the abundance of benthic macro-invertebrates, such as lobsters and crabs, as well as fish are often increased due to the provision of physical structure or the fall-off of mussels from culture structures, which provides a direct or indirect food source to these organisms. Little work has evaluated the impact of mussel culture areas in offshore areas, which are more dispersive in nature and potentially have different functioning and suites of organisms associated with them. This project evaluates the influence of an offshore aquaculture site in Îles de la Madeleine, Quebec, on the spatial distribution of macro-invertebrates and fish. These communities were sampled by visual counts using scuba diving in multiple areas inside of and outside of the farm site in spring and summer. Sampling was done directly below mussel lines and at three distances from mussel lines in the farm, as well in the same configuration in areas outside of the farm, to see if small-scale effects were evident. This work will provide managers with a better understanding of the influence of mussel farms on commercially important species.

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FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** La Société de développement de l'industrie maricole (SODIM); Ressources Aquatiques Québec (RAQ); Université du Québec à Rimouski (UQAR)

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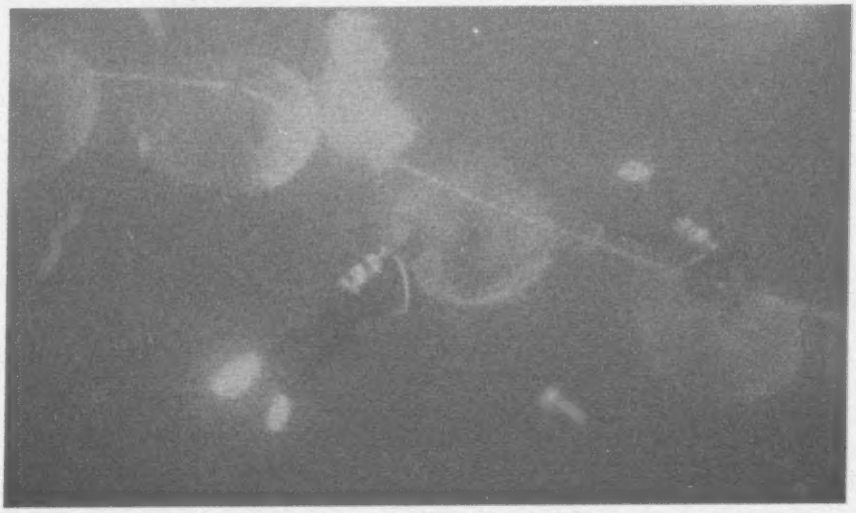
Divers quantify the abundance of benthic invertebrates and fish along transects inside of and outside of mussel culture sites offshore of Îles de la Madeleine. Photo: Chris McKindsey (DFO)

ECOLOGICAL CARRYING CAPACITY AND EVALUATION OF INDICATORS OF BENTHIC CONDITION FOR OFFSHORE MUSSEL CULTURE IN ÎLES DE LA MADELEINE

Wastes (faeces and pseudofaeces – together known as biodeposits) from filter-feeding bivalves grown in aquaculture may accumulate within and around farm sites, potentially organically enriching sediments and changing benthic communities and physiochemical indicators of this. Most work on this to date has been done within fairly protected and shallow areas where issues of ecological carrying capacity (i.e., the stocking density of farmed bivalves that will not produce unacceptable effects on, for example, benthic communities) have been widely addressed. Recently, interest in producing bivalves in more offshore locations has increased. This study is evaluating the ecological carrying capacity of the benthic environment for an offshore mussel aquaculture site in Îles de la Madeleine, Quebec, and indicators of benthic conditions. To this end, experiments are being done to measure mussel biodeposit production, which, when used to force a simple dispersal estimation model, will be used to predict patterns of benthic loading within and around a mussel farm. Benthic communities and sediment biogeochemical measures are being sampled in areas with normal levels of mussel production, as well as areas with much heightened levels of production, to determine how benthic communities are influenced by the culture activities and if standard chemical measures are appropriate to detect such effects. Results from this work will be useful in the event that producers in the area wish to seek eco-certification for their operations.



Divers work on large sediment traps to measure bio-deposit production by farmed mussels in Iles de la Madeleine. Photo: François Roy (DFO)

APR. 2013–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** La Société de développement de l'industrie maricole (SODIM); Ressources Aquatiques Québec (RAQ); Université du Québec à Rimouski (UQAR)

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MONITORING VARIABILITY OF ENVIRONMENTAL FACTORS IMPACTING TUNICATE INFESTATION ON COASTAL SHELLFISH FARMS IN NOVA SCOTIA

Results from this study may suggest an environmental factor to be used as an indicator to assess aquaculture sites (either current or future proposed sites) for their risk of infestation by the solitary Vase Tunicate (*Ciona intestinalis*) and inform siting decisions made by the government. This study may also help reduce further spread of this invasive species and the need for control treatments through the identification of sites less vulnerable to tunicate infestation.

The establishment of the Vase Tunicate, an invasive species in the waters of Nova Scotia and Prince Edward Island, has negatively impacted mussel farm productivity in these areas. Vase Tunicates grow in dense groups on mussel ropes, nets, and the mussels themselves. Aside from competing with mussels for space and potentially food, fouled gear is much more difficult to handle (during harvesting for example) and can result in crop losses. Tunicates must be removed following harvesting and in heavily fouled sites they must be removed at least once before harvest, which is both a time and resource-intensive process. Despite the various management techniques in use (e.g., pressure washing, brine dips, liming, UV treatment, electric shocks), once established, Vase Tunicates are sufficiently persistent that their presence has become a serious hindrance to the mussel industry, and in extreme cases has cost farmers their businesses. The spatial distribution of the Vase Tunicate is highly heterogeneous and could be the result of variation in environmental factors among sites. This project will examine the effect of variability of environmental factors (e.g., salinity, temperature, pH, and water movement) on the establishment and proliferation of Vase Tunicates.

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FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** La Société Aquaculture Association of Nova Scotia (AANS)

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PRODUCTION CARRYING CAPACITY FOR OFFSHORE MUSSEL CULTURE IN ÎLES DE LA MADELEINE

Bivalves feed by filtering their food from the water. The removal of plankton by great densities of farmed bivalves may exceed the ability of plankton to be replenished, which has been shown to occur in some enclosed coastal areas. Recently, interest in producing bivalves in more offshore locations has been increasing but little work has addressed issues of production carrying capacity (stocking density of bivalves at which harvests are maximized – a function of plankton resources) in these situations. In this project, the production carrying capacity of an area that is being zoned for bivalve aquaculture offshore of Îles de la Madeleine, Quebec, was evaluated. This is being done by coupling a spatially explicit hydrodynamic model and a shellfish growth model that is forced by physical variables (e.g., plankton data, temperature) that were obtained through an enhanced monitoring programme that included constant monitoring using moored instruments and on-going *in situ* sampling of key parameters (e.g., chlorophyll levels), and mussel growth measurements, May through October 2013. The results from this research will help define sustainable levels of mussel culture densities in the area and how to optimally configure mussel lines within leases.

APR. 2013–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** La Société de développement de l'industrie maricole (SODIM); Ressources Aquatiques Québec (RAQ); Université du Québec à Rimouski (UQAR)

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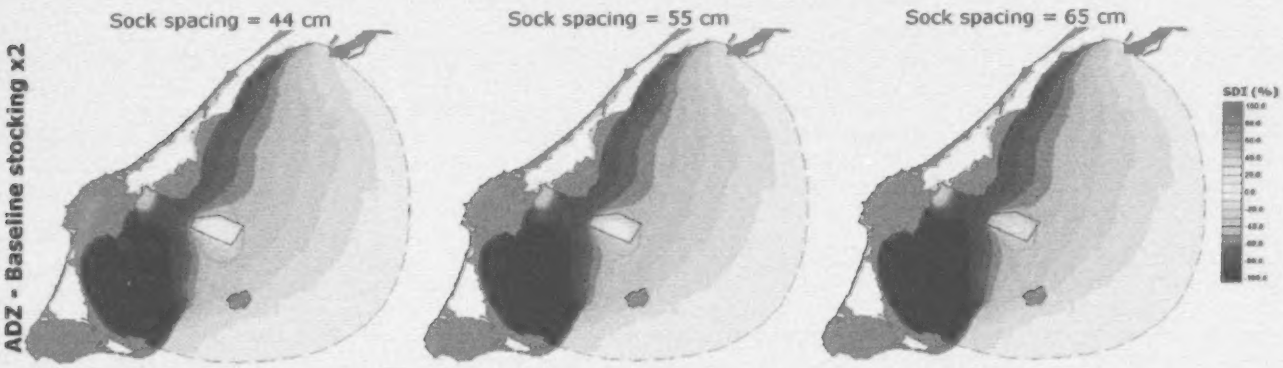

Modelled influence of proposed mussel culture zone offshore of Îles de la Madeleine on plankton concentration under different farm stocking scenarios showing Seston Depletion Index (SDI) >0 when plankton concentration is reduced compared to the far-field. Photo: Thomas Guyondet (DFO)

EFFECTS OF HUSBANDRY PRACTICES AND MITIGATION TREATMENTS ON THE LONG-TERM CONTROL OF TUNICATE INFESTATION IN PEI MUSSEL FARMS

Tunicate infestations have severely impacted the shellfish aquaculture industry in Atlantic Canada, particularly the mussel aquaculture industry in PEI. This project will investigate the relationship between availability of recruitment space, and levels of infestation by the Solitary Tunicate, *Ciona intestinalis*, in mussel culture embayments. Effects of varying mussel stock density on the evolution of infestation levels will be assessed, including the particular case of fallowing of culture leases. The study will be conducted at the scale of a typical mussel aquaculture embayment, and will entail multi-year simulations to assess the overwintering potential of tunicates. The proposed methodology will rely on numerical modelling of multi-year population dynamics of *C. intestinalis*, informed by relevant *in situ* observations. A combination of treatment and mussel stocking scenarios, in particular those obtained for the fallowing of mussel farms, will be reproduced to provide valuable information for the long-term management of bay-scale infestation levels. Results from this project will contribute to the development of bay-scale regulations for culture practices, and mitigation measures for controlling tunicate fouling on cultured mussels.

AUG. 2014–MAR. 2017

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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COMPARISON OF THE HEALTH AND CONDITION OF CULTURED MUSSELS FROM DEEP WATER AND SHALLOW WATER SITES IN NEWFOUNDLAND WITH REFERENCE TO ENVIRONMENTAL CONDITIONS, CONDITION INDEX, PHYSIOLOGICAL STRESS, AND LIPID BIOCHEMISTRY

Deep water mussel site near Pleasantview, Notre Dame Bay, NL. Photo: Harry Murray (DFO)

Little is understood about how the deep water environment specifically affects health and condition in mussels, as compared to the traditional shallow water coastal areas and how these benefits might be defined. This information will help industry make decisions regarding whether the utilization of deep water sites in Newfoundland will add increased sustainability for mussel culture in the region.

The Newfoundland mussel culture industry is poised to undergo a period of expansion in production due to increased utilization of existing approved culture sites as well as the development of new sites throughout the province. These sites are situated in sheltered near shore areas like estuaries, harbours, and shallow bays. Unfortunately, these zones can be affected by land runoff especially during times of significant precipitation and thus can be exposed to contaminants of land origin. Also, increased pressure for lease space in these areas has raised concerns with regard to carrying capacity and thus sustainability. Recently, increased interest in developing offshore and deep water bivalve culture and its associated technology has prompted Norlantic Processors Ltd., a Newfoundland based company, to begin adapting existing technology for the utilization of deep water mussel sites in the Notre Dame Bay region of the island. This project proposes to characterize and compare seasonal changes in environmental conditions in deep water and coastal shallow water mussel culture sites in Notre Dame Bay, Newfoundland, and investigate potential correlations between environment and mussel condition, physiological stress, and lipid biochemistry.

APR. 2012 – MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Norlantic Processors Ltd.

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PICOPHYTOPLANKTON CONTRIBUTION TO *MYTILUS EDULIS* GROWTH IN AN INTENSIVE CULTURE ENVIRONMENT

Autotrophic picoplankton (0.2–2.0 µm) is one of the most abundant phytoplankton components in marine ecosystems. The contribution of picophytoplankton to Blue Mussel (*Mytilus edulis*) growth was investigated in eastern Prince Edward Island (PEI), where the bulk of the Canadian suspension mussel industry is located. Flow cytometry was used to estimate the ability of mussels to retain picophytoplankton (0.2–2.0 µm) and nanophytoplankton (2–20 µm) in the field, along with size-fractioned phytoplankton biomass (chlorophyll-a), and mussel growth (shell and tissue). Retention efficiency (RE) for picophytoplankton (0.2–2.0 µm) and nanophytoplankton (2.0–20.0 µm) averaged 19.76 ± 2.03% and 60.21 ± 3.49%, respectively. RE and phytoplankton biomass were integrated into a Dynamic Energy Budget (DEB) model to investigate the contribution of picophytoplankton to mussel growth during the post-spring bloom period. When DEB simulations excluded picophytoplankton (RE = 0%), the predicted reduction in mussel growth ranged between 13.7% and 28.6%. It is concluded that the contribution of small sized phytoplankton to the mussel's energy budget is non-negligible and should be taken into account to understand interactions bivalve farming and phytoplankton dynamics.

MAY 2009–MAR. 2013

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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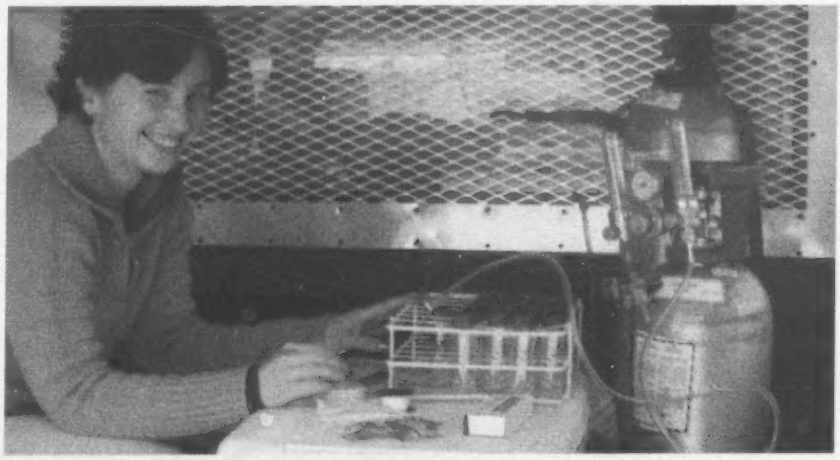
Blue Mussel (*Mytilus edulis*) farming in Prince Edward Island. Photo: Rémi Sonier (DFO)

AN INVESTIGATION OF THE LIPID AND FATTY ACID COMPOSITION OF THE BLUE MUSSEL, *MYTILUS EDULIS*, WITH REFERENCE TO PALATABILITY AND TASTE DURING CONDITIONS OF EXTENDED HOLDING

Blue Mussel (*Mytilus edulis*) culture is continuing to grow as an industry in eastern Canada and there is an increased market demand for fresh product, not just during peak seasons, but throughout the year. Consequently, wet storage facilities have become invaluable tools which allow the industry to maintain supply of their product through weather delays or stockpile their harvest for anticipated orders. The effects of extended holding by processing facilities on the biochemical composition of mussel tissue (lipid, fatty acid, and glycogen content) and meat quality (taste and palatability) remains largely unknown. This study assessed the physiological condition of cultured Blue Mussels held in a commercial wet storage facility under ambient environmental conditions. Newfoundland harvested mussels were held for one month each in fall, winter, and spring and then sampled weekly under industry standard conditions. Held mussels were compared directly with freshly harvested samples taken at the same point in time for changes in biochemical composition and quality. Results showed that while mussel condition was reduced after four weeks holding, biochemical composition was affected only by seasonality and not by holding conditions. Taste panellists were unable to differentiate between freshly harvested mussels and those kept in holding.



Biochemical composition analysis of mussel samples. Photo: Harry Murray (DFO)

APR. 2011–MAR. 2012

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP)

CO-FUNDED BY: Norlantic Processors Ltd.

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SIMPLE MODEL ESTIMATIONS OF BAY-SCALE ECOLOGICAL CARRYING CAPACITY FOR SUSPENDED MUSSEL CULTURE

Sustainability issues related to the mussel culture industry were assessed using carrying capacity predictions based on food depletion criteria. Relatively simple model predictions (indices) of the present and optimal carrying capacity status of multiple coastal embayments were provided to support future regulatory decisions, to help identify sustainable aquaculture limits (thresholds), and to aid industry towards sustainability certification. The model incorporates the most important aspects of the carrying capacity calculation which affect the supply and removal of phytoplankton in a body of water under enhanced shellfish grazing pressure; these include the time it takes for a given bivalve population to filter the bay volume (clearance time), the time needed for tides to flush a bay and re-supply external food sources (residence time), and the time required for phytoplankton growth to replace internal food resources (phytoplankton doubling time). Ecological carrying capacity is expected to be reached when the removal of phytoplankton by all bivalve farms in an area exceeds the capacity of the ecosystem to replenish this critical marine food source. Such a condition would result in adverse dietary conditions for both wild and cultured populations. Calculations using existing data for multiple major shellfish culture embayments in Canada were expressed as an index of ecological carrying capacity. These calculations have proven to be a useful tool for identifying potentially problematic aquaculture sites where further research and detailed modeling programs can be deployed.

APR. 2011–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

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Bay-scale food depletion modelling can be an effective tool for identifying and assessing bay-scale ecological carrying capacity criteria.

EVALUATION OF BLUE MUSSEL PROCESSING PLANT HOLDING SYSTEMS IN PEI

Blue Mussel (*Mytilus edulis*) processors are looking for new and improved holding systems and methods to maintain high quality product and better compete in international markets. This study compared the traditional live mussel holding system to a newer chilled recirculation system. Specifically, researchers compared water quality, oxygen distribution, holding capacity, and shelf life of mussels, as well as evaluated emersion/immersion cycles on mussel shelf life (a method that mimics the life of successful intertidal mussels which are exposed out of water at low tide) between the two holding systems.

There were important differences in oxygen concentrations and pH (acidity) between the systems. Both systems exhibited an overall decrease in dissolved oxygen with prolonged holding times. Flow rate, water flow within the tanks (overflow positioning), and length of holding period should all be carefully considered in order to keep sufficient oxygen concentrations in mussel holding tanks. There was no clear evidence that one live holding system was better than the other in terms of condition index (the ratio between dry weight and total weight) and holding capacity. Preliminary results on emersion cycles were not promising, with increased holding mortalities and no increase in shelf life.

Additional research is required in order to determine if shellfish recirculating holding systems are able to hold live shellfish for extended periods without loss of quality and shelf life. A recirculating system could potentially allow the aquaculture industry to sell live shellfish even in the event of a shellfish harvesting closure in the area, whereas, processing plants using traditional holding systems (that continuously pump water from nearby bays) could not sell their product during a closure.

APR. 2011–MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** P.E.I. Mussel King (1994) Inc.

PROJECT LEAD: Daniel Bourque (DFO)

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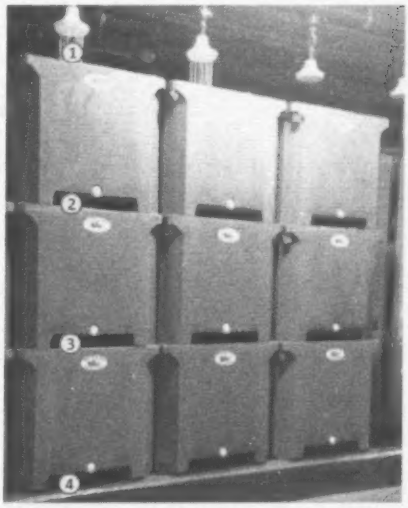
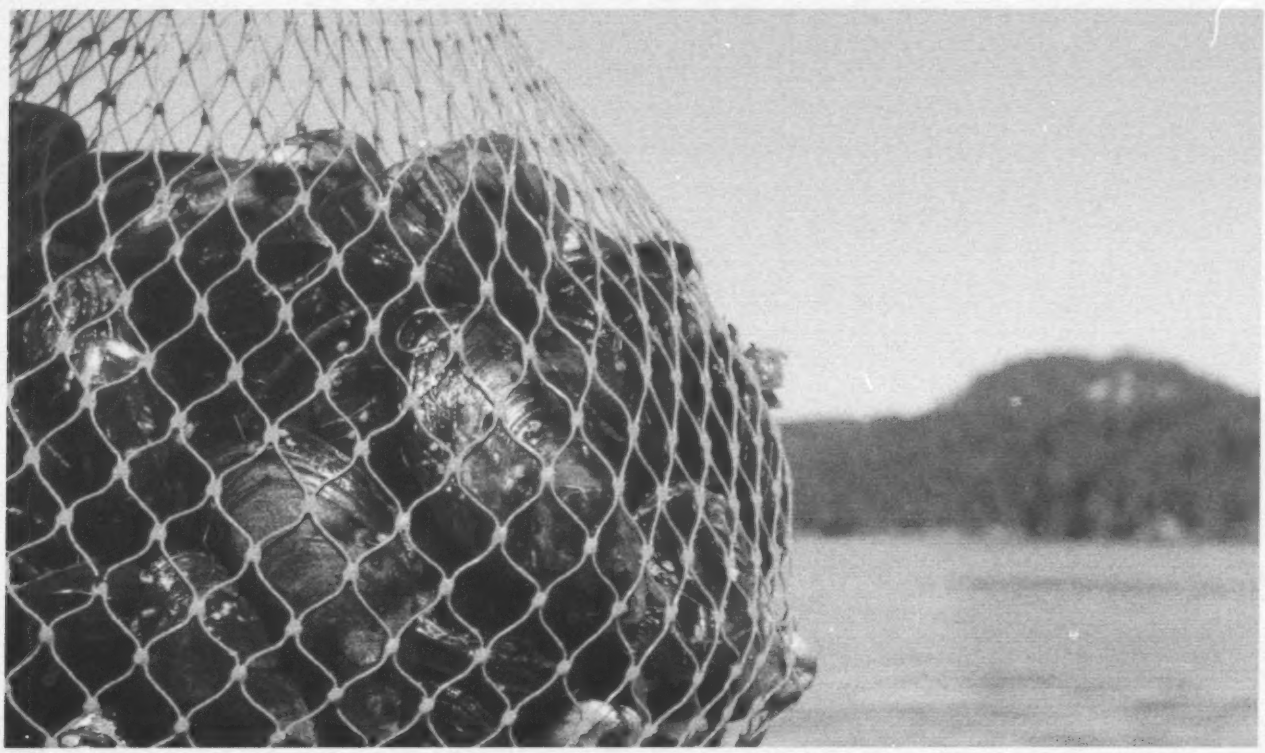
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm



Stacked live mussel holding tanks. Water is introduced at the top, which then trickles down through the tanks to the bottom. Water sampling locations are indicated by the numbered yellow circles. Photo: Daniel Bourque (DFO)



Blue Mussels. Photo: DFO

HYDRATED LIME FOOTPRINT IN MUSSEL FARMS

The PEI mussel industry controls the invasive Clubbed Tunicate, *Styela clava*, by applying hydrated lime to mussel socks. DFO, Atlantic Veterinary College (AVC), and the province of PEI collaboratively monitored in situ pH changes during liming operations in Malpeque Bay. pH sensors were attached directly onto the treated mussel sleeves; other pH sensors were towed in the near vicinity of the treated socks or moored on the estuarine seabed.

Results indicated that the sock-scale pH signature is short-lived, generally disappearing within 10 minutes after the re-immersion of socks. No water-column pH signature was detected between one to seven meters away from the treated socks, whereas faint ephemeral signatures were detected on the seabed. This information is being assessed in the context of possible impacts on non-targeted species, such as crustaceans and other bivalves. The results of this study will inform stakeholders on the potential effects of expanding mussel culture in Malpeque Bay.

JUL. 2013–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Luc Comeau (DFO)

PROJECT TEAM: Rémi Sonier, Thomas Landry (DFO)

COLLABORATORS: Jonathan Hill, John Davidson, Jeffrey Davidson (AVC); Aaron Ramsay (PEI DFARD)

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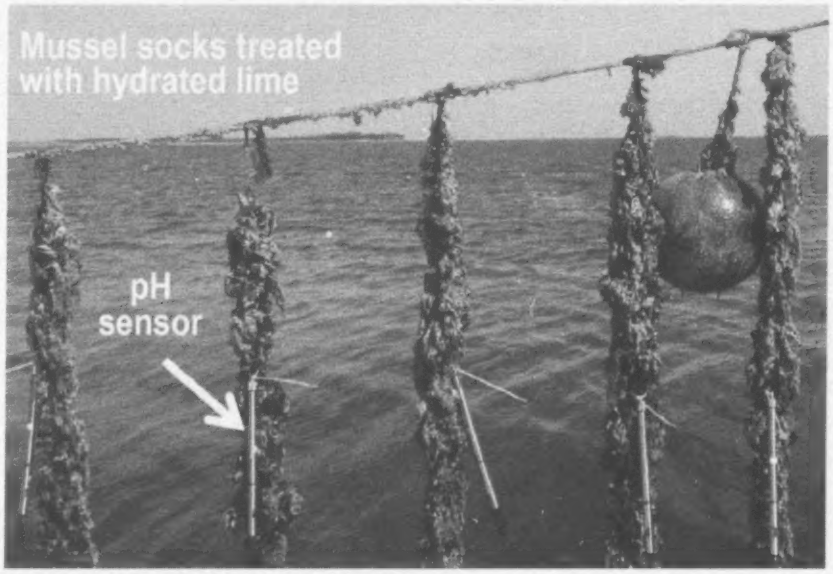

Mussel socks with pH sensors. Photo: Jonathan Hill

ASSESSMENT OF MUSSEL PRODUCTION STRATEGIES TO AVOID WILD DUCK PREDATION IN THE GRANDE-ENTRÉE LAGOON (MAGDALEN ISLANDS, QUEBEC)

Claude Poirier deploying mussel socks. Photo: Lise Chevarie (Merinov)

Predation by wild ducks has affected the mussel industry for several years and causes considerable damage on some production sites. The various duck-scaring techniques tested to date (chasing by boat, sound recordings, gunshots, etc.) did not yield the desired results because they require a lot of energy and sometimes become ineffective when the birds become used to them.

In the Magdalen Islands (Quebec), the Grande-Entrée lagoon contains the only mussel culture site currently experiencing this problem. To support the industry, sock transfer strategies to sites that are free from ducks during critical periods of predation, are currently being tested. These scenarios involve high-density socking before the fall transfer and a second standard-density socking before the socks are returned to the usual culture site at the beginning of the summer. A third strategy is to install protective nets around culture longlines. This method, inspired by trials conducted in Norway, involves deploying nets perpendicularly around the lines to cover the entire water column. Buoys are used to keep the net approximately 60 cm above the water surface. The economics of the scenarios will be considered and will help determine the efficiency and profitability of each.

If the results are conclusive, they could lead to attractive benefits for a part of the mussel industry that must deal with this problem and its many consequences year after year.

OCT. 2013–MAR. 2016

FUNDED BY: MAPAQ; Ministère des Finance et Économie (MFE) **CO-FUNDED BY:** Merinov; Grande-Entrée Aquaculture Inc.; Culti-Mer Inc.; Biomer

LEAD: Lise Chevarie (Merinov)

PROJECT TEAM: Jean-François Laplante (Merinov); Élisabeth Varennes (UQAR)

COLLABORATORS: Grande-Entrée Aquaculture Inc.; Culti-Mer Inc.; Biomer

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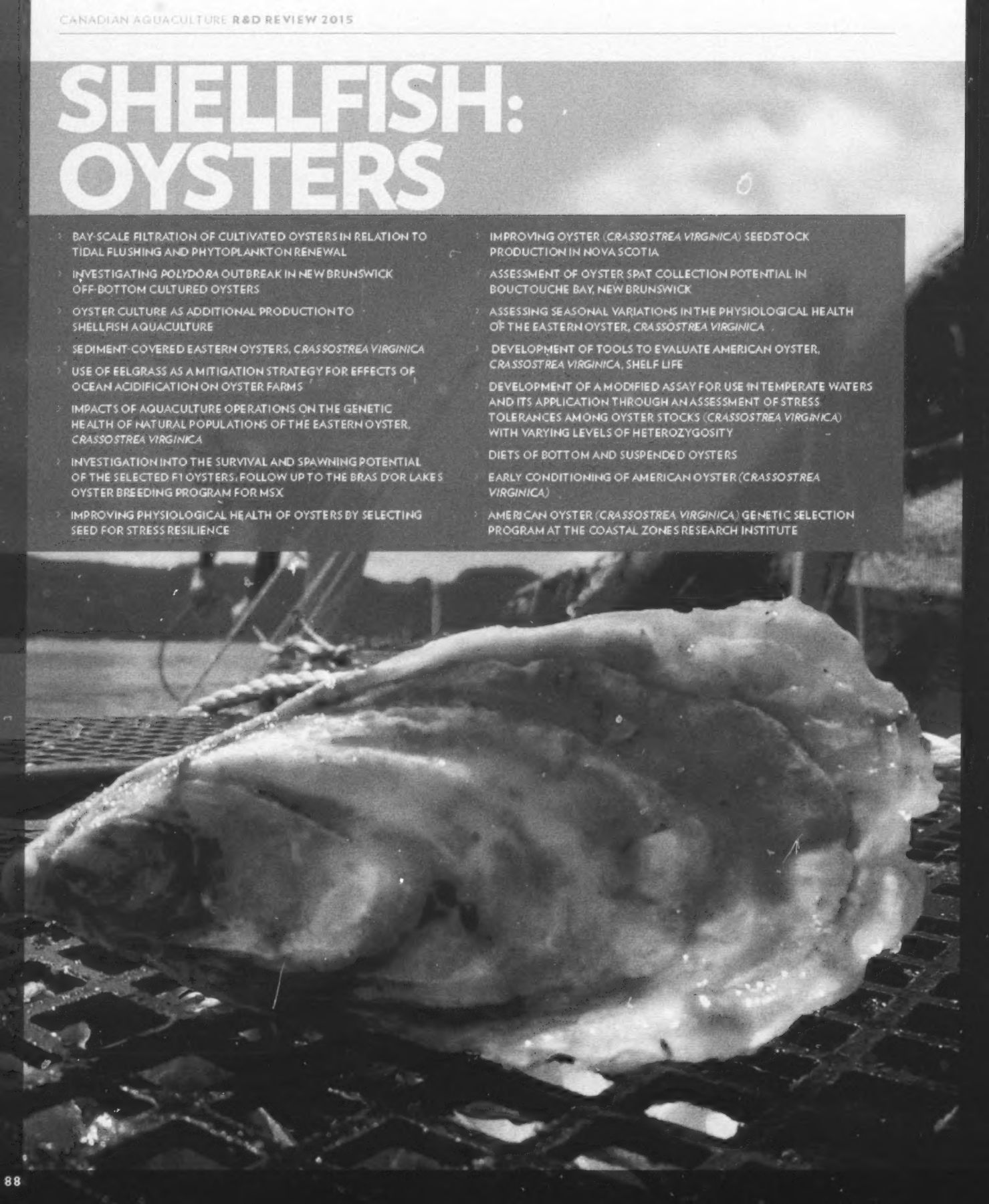
SHELLFISH: OYSTERS

- BAY-SCALE FILTRATION OF CULTIVATED OYSTERS IN RELATION TO TIDAL FLUSHING AND PHYTOPLANKTON RENEWAL
- INVESTIGATING *POLYDORA* OUTBREAK IN NEW BRUNSWICK OFF-BOTTOM CULTURED OYSTERS
- OYSTER CULTURE AS ADDITIONAL PRODUCTION TO SHELLFISH AQUACULTURE
- SEDIMENT-COVERED EASTERN OYSTERS, *CRASSOSTREA VIRGINICA*
- USE OF EELGRASS AS A MITIGATION STRATEGY FOR EFFECTS OF OCEAN ACIDIFICATION ON OYSTER FARMS
- IMPACTS OF AQUACULTURE OPERATIONS ON THE GENETIC HEALTH OF NATURAL POPULATIONS OF THE EASTERN OYSTER, *CRASSOSTREA VIRGINICA*
- INVESTIGATION INTO THE SURVIVAL AND SPAWNING POTENTIAL OF THE SELECTED F1 OYSTERS; FOLLOW UP TO THE BRAS D'OR LAKES OYSTER BREEDING PROGRAM FOR MSX
- IMPROVING PHYSIOLOGICAL HEALTH OF OYSTERS BY SELECTING SEED FOR STRESS RESILIENCE
- IMPROVING OYSTER (*CRASSOSTREA VIRGINICA*) SEEDSTOCK PRODUCTION IN NOVA SCOTIA
- ASSESSMENT OF OYSTER SPAT COLLECTION POTENTIAL IN BOUCTOUCHE BAY, NEW BRUNSWICK
- ASSESSING SEASONAL VARIATIONS IN THE PHYSIOLOGICAL HEALTH OF THE EASTERN OYSTER, *CRASSOSTREA VIRGINICA*
- DEVELOPMENT OF TOOLS TO EVALUATE AMERICAN OYSTER, *CRASSOSTREA VIRGINICA*, SHELF LIFE
- DEVELOPMENT OF A MODIFIED ASSAY FOR USE IN TEMPERATE WATERS AND ITS APPLICATION THROUGH AN ASSESSMENT OF STRESS TOLERANCES AMONG OYSTER STOCKS (*CRASSOSTREA VIRGINICA*) WITH VARYING LEVELS OF HETEROZYGOSITY
- DIETS OF BOTTOM AND SUSPENDED OYSTERS
- EARLY CONDITIONING OF AMERICAN OYSTER (*CRASSOSTREA VIRGINICA*)
- AMERICAN OYSTER (*CRASSOSTREA VIRGINICA*) GENETIC SELECTION PROGRAM AT THE COASTAL ZONES RESEARCH INSTITUTE

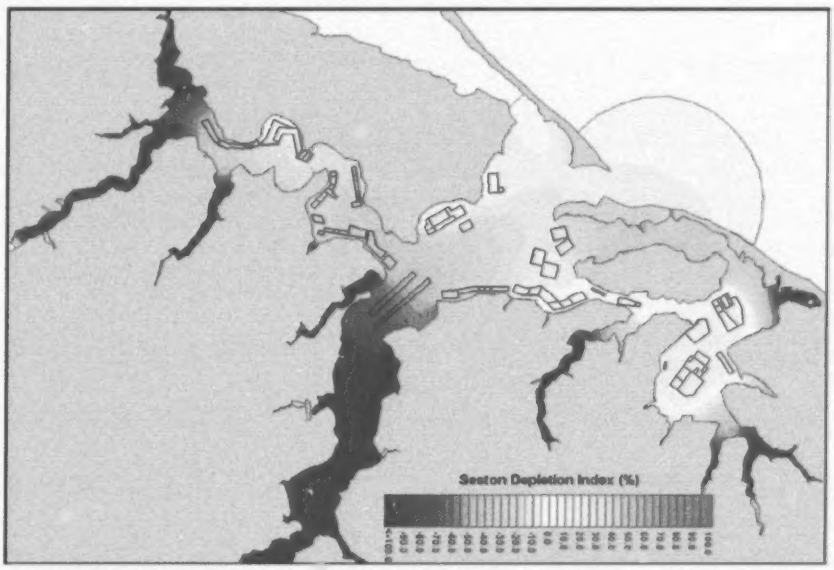


BAY-SCALE FILTRATION OF CULTIVATED OYSTERS IN RELATION TO TIDAL FLUSHING AND PHYTOPLANKTON RENEWAL

With the recent expansion of oyster (*Crassostrea virginica*) culture within Village Bay, New Brunswick, there were concerns that this oyster population may be filtering phytoplankton from the bay faster than it could be replenished. To address this concern, this project examined the filtration capacity of oysters against the renewal rates of water and phytoplankton within the bay. Modelling tools were used to describe the relationship between a breach opening in the sand dune occurring at the head of the bay and its potential effect on food fluxes.

The results of the modelling showed that phytoplankton production within Village Bay is greater than that brought in by the tides and currents, suggesting that food production within the bay is sufficient to support existing oyster culture levels. Only 10–30% of water movement in the bay could be attributed to the breach. This suggests that, currently, the breach has very little impact on the water movement within the bay, and that the majority of the oyster food is being produced within the bay rather than coming from outside waters entering through the breach.

This research has provided relevant information to regulators to ensure the effective management of this industry and to help determine whether further expansion of the oyster culture operations should occur in Village Bay. Future studies should continue to monitor the breach to determine the potential effect of further erosion on food availability within the bay.



Spatial distribution of the Seston Depletion Index (SDI) predicted by the model in the actual conditions of oyster culture development, primary production, and water renewal. Where yellow = approx 20% depletion, dark blue = 80% production (Guyondet et al., submitted).

APR. 2010–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP)

CO-FUNDED BY: King Aquaculture

PROJECT LEADS: Rémi Sonier, Luc Comeau (DFO)

COLLABORATORS: King Aquaculture

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INVESTIGATING *POLYDORA* OUTBREAK IN NEW BRUNSWICK OFF-BOTTOM CULTURED OYSTERS

A better understanding of the increased intensity and prevalence of *Polydora* related to environmental conditions and their impact on oyster health would assist industry in developing management and mitigation strategies.

Known simply as a "mudworm" or "blisterworm", *Polydora websteri* has the ability to bore into the shells of live and dead shellfish. Commonly found in intertidal and subtidal areas in Atlantic Canada, its presence among New Brunswick oyster populations has normally been minor and usually of low intensity with burrows containing little or no mud. However, there have been sporadic increases of infestation rates observed in off-bottom (or suspension) oyster growing sites in New Brunswick. Some reports have indicated that heavy infestations can result in low meat quality, abscesses, alteration of growth patterns, and weakened shells (increasing predator susceptibility). This unusual increase could ultimately lead to serious impacts on oyster populations and result in economic losses for the aquaculture industry. To help identify the current impact of *Polydora* on New Brunswick oyster growing areas, this project aims to: (1) document the presentation and level of the infestation of *Polydora*; (2) document the impact of *Polydora* on overall oyster health; and (3) document distribution and infestation level of *Polydora* in relation to environmental conditions.

APR. 2014–MAR. 2016

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Huîtres Aquador Oysters Inc.

PROJECT LEADS: Daniel Bourque, Mary Stephenson (DFO)

COLLABORATORS: Huîtres Aquador Oysters Inc.

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

OYSTER CULTURE AS ADDITIONAL PRODUCTION TO SHELLFISH AQUACULTURE

The objective of this project is to assess the bio-technical feasibility of this culture in the Îles de la Madeleine and the Gaspé Peninsula. To do this, the study was divided into three components. Component A's specific objective was to test three suspension culture techniques with two oyster size classes (30–40 mm and 50–60 mm) and two oyster stocks (Bouctouche and Caraquet). These three techniques were assessed by: (1) comparing oyster survival and growth; (2) evaluating oyster quality; and (3) evaluating the time required for the oysters in each size class to reach the minimum market size (cocktail) (> 65 mm). Component B concerned oyster conditioning. The sexual maturation potential for oysters during the summer in the cold waters of the Gaspé Peninsula and the Islands was assessed. Component C assessed the technical/economic feasibility of such culture in Quebec's coastal waters.

Unlike the results from the Gaspé Peninsula, the results from the Islands are very encouraging. Oysters (50–60 mm) purchased in Bouctouche and farmed in the Havre-aux-Maisons lagoon had an average growth of 28 mm and 25 mm over two years when tested on ropes and in lantern nets, respectively. The result is similar for Bouctouche oysters with an initial size of 30–40 mm, growing to 31 mm in two years. Recovery rates (including losses through mortality and fall-off) were over 80% in the first year and 53% after the second year for rope-grown oysters. These rates were even more encouraging for oysters placed in lantern nets.

OCT. 2011–DEC. 2014

FUNDED BY: Economic Development Canada for Quebec Regions (EDC); Innovamer program (MAPAQ)

LEAD: Lisandre Solomon (Merinov)

PROJECT TEAM: Isabelle Lemieux (Gaspé Peninsula lead); Carole Cyr, Aurelie Licois

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Rope-grown oysters. Photo: Lisandre Solomon

Cultured oyster. Photo: Lisandre Solomon

SEDIMENT-COVERED EASTERN OYSTERS, *CRASSOSTREA VIRGINICA*

In Gulf of St. Lawrence estuaries, mesh bags containing cultivated oysters are lowered onto the estuarine seabed. This is initiated in October/November and recovered five to six months later, i.e., after the thick winter ice cover breaks up and moves offshore. Oyster farmers periodically report mortalities when bags are recovered from the seabed in the spring. The dead oysters have dark gaping shells containing black anoxic sediments and traces of still-decomposing tissues. It is suspected that oysters are vulnerable to sedimentation and burial during the winter period, when they remain unattended for a prolonged period of time.

Presently there are no industry guidelines with respect to the optimal timing for either lowering bags onto soft bottoms in autumn or recovering these bags in spring. Some growers lower bags in early October to avoid autumnal storms and the breaking of new shell growth. Others wait until the water temperature falls below 4°C and oysters become metabollicaly quiescent. This project will assess whether: (1) there is a cause-effect relationship between winter burial and oyster health; and (2) the timing of burial in autumn has any modulating effect on winter survival.

JUL. 2014–MAR. 2016

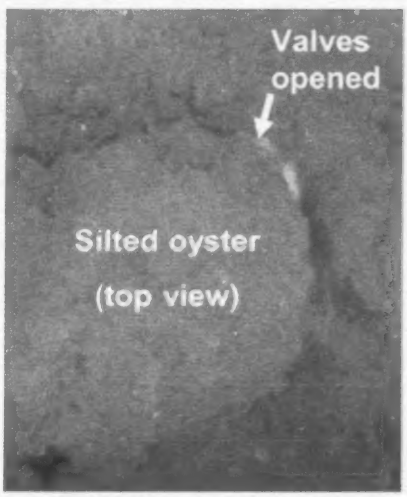
FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** L'Étang Ruisseau Bar Ltd.

PROJECT LEAD: Luc Comeau (DFO)

PROJECT TEAM: André Mallet, Claire Carver (L'Étang Ruisseau Bar Ltd.)

COLLABORATORS: Jeffrey Davidson (UPEI)

CONTACT: Luc.Comeau@dfo-mpo.gc.ca



Photograph of buried oyster that successfully managed to expulse the overlying silt away from its shell edge. Photo: Luc Comeau (DFO)

USE OF EELGRASS AS A MITIGATION STRATEGY FOR EFFECTS OF OCEAN ACIDIFICATION ON OYSTER FARMS

Preservation, restoration, and conservation of eelgrasses has been proposed by various governmental agencies as a remediation strategy for coastal habitats impacted by ocean acidification (OA), but this hypothesis has not been tested. This is one of the first tests to examine whether it will be a viable remediation option.

Climate change has been associated with declines of coastal organisms and this is impacting wild and farmed fisheries. In the case of organisms with calcifying shells, OA is a particular threat and has led to closures of oyster aquaculture sites and production losses. This is not only an economic loss, but an ecological one as well, as oysters provide numerous ecosystem functions, including water filtration and formation of reef habitats. One possible mitigation strategy for OA in soft sediment coastal habitats is by co-culturing seagrass species with OA sensitive species. Seagrasses can grow faster in high CO_2 environments and fauna associated with healthy seagrass meadows may benefit from OA environments, in part because seagrasses remove dissolved inorganic carbon from the water column during photosynthesis. This photosynthetic activity can create an OA buffer that extends beyond the seagrass canopy, providing a refuge for pH-sensitive organisms that reside in and close to these systems.

Using mesocosm experiments, we are testing the following hypotheses: (1) Eelgrass presence increases seawater pH, alkalinity and the aragonite saturation state; (2) Eelgrass presence improves oyster survival and growth rates; and (3) Eelgrass health increases with decreasing ocean pH.

MAY 2014–APR. 2015

FUNDED BY: Canada Excellence Research Chair (CERC) – Aquatic Epidemiology, UPEI

PROJECT LEADS: Maya Groner, Jeff Davidson (UPEI)

PROJECT TEAM: John Bucci (U New Hampshire); Colleen Burge (U Maryland); Carolyn Friedman, Sandy Wyllie-Echeverria (U Washington); Ruth Cox (UPEI)

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While healthy Eelgrass meadows may provide local amelioration of the detrimental effects of ocean acidification, degraded meadows, such as this likely have little impact on ocean pH. Photo: Maya Groner (UPEI)

Maya Groner seagrass sampling. Photo: Maya Groner (UPEI)

IMPACTS OF AQUACULTURE OPERATIONS ON THE GENETIC HEALTH OF NATURAL POPULATIONS OF THE EASTERN OYSTER, *CRASSOSTREA VIRGINICA*

This information will allow for both a better assessment of the genetic health of *Crassostrea virginica* populations in the Maritimes, and for the establishment of hatchery-based breeding programs.

Oyster farmers currently rely on wild-caught seed to stock their aquaculture sites. The number and quality of seed, however, is highly variable from year-to-year and juvenile oysters must often be sold and transported from regions with a high seed set (abundance) to regions with a poor seed set. To address this issue, a commercial-scale hatchery in New Brunswick is currently being developed to provide adequate spat (oyster seed) to oyster farms within the Maritimes. The potential impact of hatchery-spawned oysters, as well as transplanted wild-caught spat, on the genetic integrity of neighboring wild oyster beds greatly depends on the factors underlying the genetic structure of natural populations. Conversely, the health and vigour of cultured oysters depends on the quality of available spat, whether from wild-caught sources or hatchery production.

Additionally, this project will examine genetic diversity between populations of the Eastern Oyster, identify functional diversity in terms of health indicators such as condition index, growth, survival, and reproduction, as well as evaluate the potential impacts of gene flow between wild and cultivated oyster populations.

The goal of this project is to evaluate the genetic sequence of natural oyster populations through the creation of a high-density linkage map for the molecular markers associated with functional diversity in the Eastern Oyster.

APR. 2013–MAR. 2017

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** L'Étang Ruisseau Bar Ltd.

PROJECT LEAD: Mark LaFlamme (DFO)

COLLABORATORS: L'Étang Ruisseau Bar Ltd.

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INVESTIGATION INTO THE SURVIVAL AND SPAWNING POTENTIAL OF THE SELECTED F1 OYSTERS: FOLLOW UP TO THE BRAS D'OR LAKES OYSTER BREEDING PROGRAM FOR MSX

This project will allow Fisheries and Oceans Canada to protect this distinct oyster population, while supporting the sustainable growth of the oyster farming industry in Nova Scotia.

Native American Oyster (*Crassostrea virginica*) populations in the Bras d'Or Lakes region of Nova Scotia have been in decline due to a combination of over-fishing, degradation of habitats and most recently, the appearance of the MSX parasite (*Haplosporidium nelsoni*) and the Malpeque disease. There is a need to rejuvenate the depleted private aquaculture leases and public oyster beds, however, the importation of oysters from outside the Bras d'Or Lakes is currently not permitted in order to protect the native oysters from exposure to these diseases. Aquaculture and commercial growers must then rely on resident populations for future culture and wild population enhancement activities. Recent research on this issue has initiated a selective breeding program designed to provide the necessary disease resistant/tolerant spat to rebuild the native population. This project will determine the spawning potential and survivorship of first generation (or F1) bred to be resistant/tolerant to MSX to support restoration efforts within the Bras d'Or Lakes and ultimately Atlantic Canada should the MSX parasite be discovered elsewhere.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Eskasoni Fish and Wildlife Commission

PROJECT LEAD: Benedikte Vercaemer (DFO)

COLLABORATORS: Eskasoni Fish and Wildlife Commission

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IMPROVING PHYSIOLOGICAL HEALTH OF OYSTERS BY SELECTING SEED FOR STRESS RESILIENCE

Having efficient and resilient oysters will ensure that if faced with a pathogen or environmental stressor, oysters will have an increased capacity to launch an immune response to pathogens.

Successful oyster culture is dependent on the use of seed that can grow well in both optimal and stressful environmental conditions. The amount of energy reserves, or the ability to produce energy from food intake, dictates how long shellfish can survive in a stressful environment or when challenged by a disease. Access to a consistent supply of high quality and resilient seed stocks (i.e., those with the capacity to launch an immune response when faced with pathogens or withstand fluctuations in salinity and temperature associated with climate change) has been identified as a key constraint for the continued viability and expansion of the Eastern Oyster industry in Atlantic Canada. Selecting oysters that are more efficient (lower metabolic need, better feed conversion, and lower reproductive effort) and have increased resistance to deal with stressful events (lower stress response) will ultimately be healthier and thus have greater resilience to pathogens and environmental changes. This project will identify genetic markers in the Eastern Oyster associated with metabolic and feed conversion efficiency with the goal of producing a first generation crop of oysters that display these particular traits and monitor their success under various growing conditions.

APR. 2014–MAR. 2017

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** L' Écloserie Acadienne Ltd.

PROJECT LEAD: Denise Méthé (DFO)

COLLABORATORS: L'Écloserie Acadienne Ltd.

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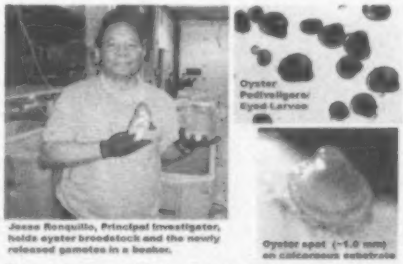
IMPROVING OYSTER (*CRASSOSTREA VIRGINICA*) SEEDSTOCK PRODUCTION IN NOVA SCOTIA

The demand for oyster in the USA and European markets is increasing, but the traditional sources of supply have been faced with increasing stresses due to both anthropological causes (e.g., oil spill in the Gulf of Mexico) and extreme environmental changes. The international markets are seeking supply from Canadian waters, but the production of oysters in Atlantic Canada, particularly from Nova Scotia, could not cope with the increasing demand. Recognizing this great market opportunity, the shellfish producers in Nova Scotia approached NS Department of Fisheries and Aquaculture (NSDFA) and the Aquaculture Centre at Dalhousie University to assist the industry to improve oyster production in the province. With financial assistance from NSDFA and Gulf Aquaculture Association (GAA), Jesse Ronquillo and his research team developed innovative hatchery procedures for improved method in oyster seedstock production using various spawning induction techniques and continuous production of selected microalgal species rich in omega-3 fatty acids for faster growth and increased survival rate of seedstock. More than 500 million pediveligers or eyed-larvae were produced for remote setting and grow-out operations of shellfish growers in Northumberland Strait.


Jesse Ronquillo, Principal Investigator, holds oyster broodstock and the newly released gametes in a beaker.
Oyster Pediveliger/ Eyed-Larvae
Oyster spat (~1.0 mm) on calcareous substrate

Spawning and seedstock production of American Oyster. Photo: Jesse Ronquillo (UBC)

The inexpensive and innovative hatchery production techniques developed through the collaborative project can be adopted by shellfish growers to produce oyster seedstock without extensive investment on costly infrastructure and equipment. The use of newly developed technology for the production of healthy and good quality oyster seedstock for remote setting will enhance shellfish production in Nova Scotia.

MAR. 2012–OCT. 2012

FUNDED BY: Nova Scotia Department of Fisheries and Aquaculture (NSDFA)
CO-FUNDED BY: Gulf Aquaculture Association (GAA)

PROJECT LEAD: Jesse Ronquillo (UBC)

PROJECT TEAM: Audrie-Jo McConkey (Dalhousie U)

COLLABORATORS: Paul Budrewski (GAA); Ronakkumar Desai (Dalhousie U)

CONTACT: Jesse.Ronquillo@ubc.ca

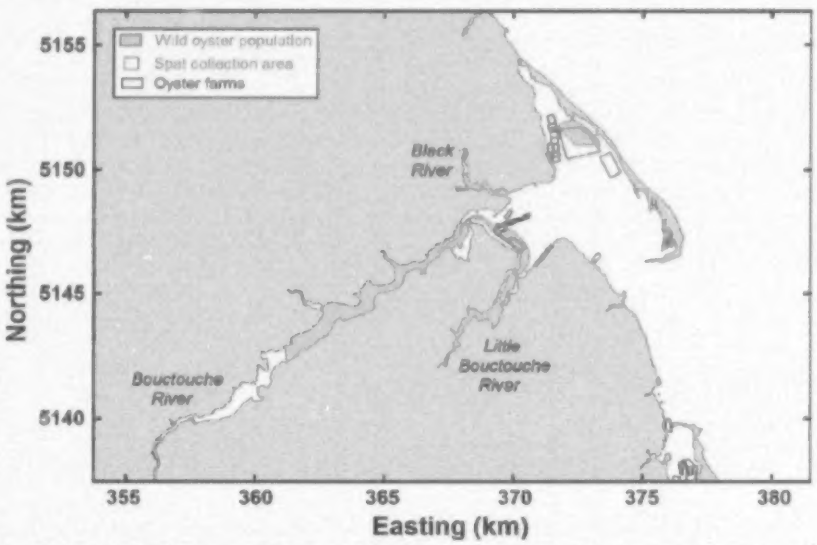
ASSESSMENT OF OYSTER SPAT COLLECTION POTENTIAL IN BOUCTOUCHE BAY, NEW BRUNSWICK

Results from this study will help inform the spat collection in Bouctouche Bay and the management of oyster seed on a larger scale to assist the development of the New Brunswick oyster culture industry.

The oyster culture industry is an economic sector in active development in eastern New Brunswick. In the southern part of this region, the industry relies quasi-entirely on a single spat collection site located in Bouctouche Bay to acquire its stocks. Little is known about the influence of environmental conditions on the success of spat collection in this bay. In the context of this project, an FVCOM hydrodynamic model is presently being developed to represent the circulation within the bay and its exchange with the Gulf of Saint Lawrence under natural forcing. A particle tracking model will then be used to reproduce the transport of oyster larvae. Different scenarios will be tested to investigate the effects of environmental forcing (wind, river discharge), as well as the influence of the potential future changes in the geomorphology of the sand barrier enclosing Bouctouche Bay on the oyster larvae distribution at the time of settlement.

APR. 2013–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Entreprise Baie Acadienne Ltd.



Map of Bouctouche Bay, NB, showing the narrow, elongated sand barrier and locations of wild oyster populations, oyster farms, and the spat collection area. Photo: Thomas Guyondet (DFO)

PROJECT LEAD: Thomas Guyondet (DFO)

PROJECT TEAM: Luc Comeau (DFO); Marie-Josée Maillet (Department of Agriculture, Aquaculture and Fisheries, NB); Serge Jolicoeur (U Moncton); Dominique Bérubé (Department of Natural Resources, NB)

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

ASSESSING SEASONAL VARIATIONS IN THE PHYSIOLOGICAL HEALTH OF THE EASTERN OYSTER, *CRASSOSTREA VIRGINICA*

Cumulative mortality is a major issue within oyster culture. Under optimal conditions, a mortality of 5% per year is often observed, however, these numbers can vary considerably between lease sites. Producers compensate for these losses by increasing the number of oysters cultivated on their leases. However, increasing the number of oysters on each lease can greatly impact the environmental footprint of the site. Valuable resources within the ecosystem are lost (e.g., phytoplankton, nutrients, etc.) and on-site biodeposition is increased, without any return to the industry or consumers in terms of more oysters. This environmental impact becomes even greater in areas of reduced water exchange and areas of maximised carrying capacity. In New Brunswick, oyster mortalities appear to be closely related to environmental factors (e.g., temperature, salinity, etc.) and husbandry or rearing practices. The physiological health of the animal can determine how well it adapts and recovers from exposure to potential stressors. This study will assess variations in the health and condition of oysters (*Crassostrea virginica*) in New Brunswick in response to environmental changes to identify critical periods of physiological stress. This information will allow the development of management plans and best practices to help oyster producers avoid supplementary stressors, thus reducing mortalities and optimizing resource utilization. This could lead to more environmentally responsible operating practices for the oyster culture industry.

APR. 2012–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** La Maison Beausoleil Inc.

PROJECT LEAD: Daniel Bourque (DFO)

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

DEVELOPMENT OF TOOLS TO EVALUATE AMERICAN OYSTER, *CRASSOSTREA VIRGINICA*, SHELF LIFE

Growers in Atlantic Canada have indicated that there are seasonal variations in oyster shelf life. Therefore, there was a need for the development of simple and reliable shelf life evaluation and prediction tools to ensure quality. This research focused on the development of tools or techniques to determine the shelf life of oysters (*Crassostrea virginica*) and predict oyster shelf life prior to storage. Several instruments and techniques were evaluated to verify their usefulness in determining and predicting oyster shelf life. The tools were chosen keeping in mind that they should be practical for use by the industry. The objective of developing these tools was to permit industry to confidently stamp their product with a best before date to assure high product quality.

Sampling oyster hemolymph (blood) for assessment of potential shelf life evaluation tools. Photo: Daniel Bourque (DFO)

The osmometer, salinity refractometer, ion selective ammonia probe, and possibly pH meter were identified as potential tools for evaluating oyster shelf life during cold storage. Although the total protein refractometer and Brix meter (for sugar content measurement) were not identified as definite tools for predicting oyster shelf life, it is felt that protein and sugar concentrations in the oysters blood still have the potential to be useful indicators. Additional studies on seasonal variations while taking into account environmental conditions (e.g., salinity) at sample sites are required to validate these potential tools.

The tools developed through this research will help the aquaculture industry to determine the shelf life and quality of oysters before they are marketed. These tools coupled with future research on seasonal variations in shelf life should allow the shellfish aquaculture industry to confidently apply a best before date to their product based on time of harvest to assure the quality of the product.

APR. 2011–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** La Maison BeauSoleil Inc.

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DEVELOPMENT OF A MODIFIED ASSAY FOR USE IN TEMPERATE WATERS AND ITS APPLICATION THROUGH AN ASSESSMENT OF STRESS TOLERANCES AMONG OYSTER STOCKS (*CRASSOSTREA VIRGINICA*) WITH VARYING LEVELS OF HETEROZYGOSITY

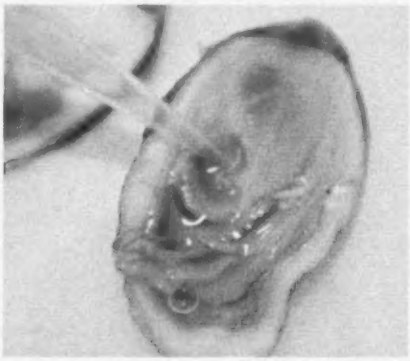
Many factors can contribute to oyster mortality and for the most part these factors are related to stress. Biomarkers that detect stress levels in oysters can help mitigate oyster losses leading to greater sustainability and productivity for the aquaculture industry. The neutral red retention assay (NRA) is a general biomarker that can detect stress-related responses (lysosomal membrane destabilization) before other disturbances such as disease, mortality, or population level changes occur. This study explored the validity of a modified NRA for use in temperate waters and evaluated the seed quality of oyster stocks from eastern New Brunswick using metabolic rate measurements, multi-locus heterozygosity, and thermal stress response (using NRA_{MOD}) as indicators.

The effect of hemolymph osmolality on the NRA outcome in oysters exposed to low water temperatures was verified in a controlled setting. Based on these findings, it is proposed that NRA_{MOD}, which uses filtered mantle fluid of the oysters, be used as an alternative to NRA when measuring lysosomal membrane destabilization of oysters in cold water.

Physiologically fit oysters that maintain vital functions with less energy have more energy available to dedicate to stress

Oysters (*Crassostrea virginica*) in treatment tanks during laboratory experiment. Photo: Denise Méthé (DFO)

responses and in turn show lower mortality rates. Based on metabolic measurements and thermal stress responses (using NRA_{MOD}), our results suggest that oyster stocks from the prominent collection areas in eastern New Brunswick (Caraquet, Miramichi, and Bouctouche) are similar in terms of their physiological fitness. However, Miramichi oyster stocks had a significantly lower level of heterozygosity compared to the other stocks. For this reason, the aquaculture industry in New Brunswick may benefit from further



Sampling hemolymph from pericardial cavity of an oyster (*Crassostrea virginica*) with a pipette. Photo: Denise Méthé (DFO)

examination into survival curves of Miramichi oyster stocks under stressful conditions as a means to provide further clarify on seed quality.

APR. 2011–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Elsipogtog Fisheries

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DIETS OF BOTTOM AND SUSPENDED OYSTERS

Oyster aquaculture in Prince Edward Island (PEI) is changing from traditional bottom to suspended culture methods. There are several advantages to suspending oyster stocks in the upper water column. This strategy protects stock from benthic predators and enhances growth by positioning oysters in a relatively warm and elevated food flux environment. In addition, oysters grown in suspension have a tendency to develop round shells ornamented with radial ridges and foliated processes. By contrast, oysters grown on soft, muddy bottoms tend to develop elongated and sparsely ornamented shells.

Several lease holders in the Trout River (PEI) system are seeking to convert from bottom to suspended culture. To improve the parameterization of carrying capacity models, this project evaluated whether bottom and suspended oysters compete for the same food resources within the system. Fatty acid analyses revealed that microalgae is the major (70%) dietary constituent, regardless of the culture technique. However, bottom oysters consumed more diatoms and less flagellates when compared to suspended oysters. Therefore an oyster's diet is dependent in part upon the cultivation technique.

MAY 2012–MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory research (DFO – PARR)

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PROJECT TEAM: Luc Comeau, Thomas Guyondet (DFO); Réjean Tremblay (UQAR/ISMER)

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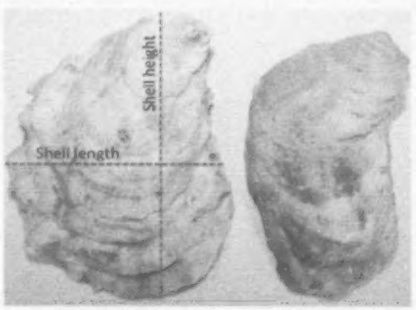

Suspended oyster **Bottom oyster**

Morphology of a suspension grown oyster (left) vs a bottom grown oyster (right). Photo: Luc Comeau (DFO)

EARLY CONDITIONING OF AMERICAN OYSTER (*CRASSOSTREA VIRGINICA*)

The ability to control the spawning period is one of the main advantages of hatcheries, especially for those producing animals cultured in the wild later on, such as the American Oyster (*Crassostrea virginica*). An early spawning allows transferring larger animals at the beginning of the natural growth period, which can reduce the production cycle by up to one year. The present project will look at the effects of broodstock overwintering periods of two and four weeks, broodstock fattening periods of two and four weeks, and the combination of both variables. Results will serve to develop a protocol on oyster broodstock conditioning and produce quality larvae in November of each year (i.e., almost eight months before spawning in nature). The number of eggs, the percentage of D-stage larvae recovered as well as the survival and growth at seven days will be monitored and considered as success indicators. A spawning in November could allow transferring 15-20 mm spats to grow-out sites in early May.

APR. 2014–APR. 2015

FUNDED BY: New Brunswick Department of Agriculture, Aquaculture and Fisheries (NBDAFF)

PROJECT LEAD: Rémy Haché (CZRI)

PROJECT TEAM: Mélanie DeGrâce, Raoul Lanteigne, Pascale Comeau, André Dumas (CZRI)

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AMERICAN OYSTER (*CRASSOSTREA VIRGINICA*) GENETIC SELECTION PROGRAM AT THE COASTAL ZONES RESEARCH INSTITUTE

The first phase of the American Oyster (*Crassostrea virginica*) breeding program is to produce at least 100 families for each one of the three populations of origin in order to create a robust basis for effective and sustainable genetic selection. The Coastal Zones Research Institute (CZRI) works with three different populations coming from three different bays: Bouctouche, Caraquet, and Miramichi. Individuals collected randomly in those bays and reared at nearby aquaculture sites have been used as broodstock. Breeding success is rather low for shellfish due to gamete incompatibility, a phenomenon commonly observed with marine invertebrates. Therefore, half-sib breeding schemes have been adopted were one male fertilises three different females separately. From the 109 crosses performed in 2014, 20 families were transferred to sea. The number of families was five from Bouctouche, five from Caraquet and ten from Miramichi. From the experience gained in 2014, the team at CZRI expects to produce a total of 100 families in 2015.

MAY 2012–AUG. 2014

FUNDED BY: New Brunswick Department of Agriculture, Aquaculture and Fisheries (NBAAF)

PROJECT LEAD: Rémy Haché (CZRI)

PROJECT TEAM: Mélanie DeGrâce, Raoul Lanteigne, Pascale Comeau (CZRI)

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Research platform, CCGS *Vector*, working in Baynes Sound, British Columbia. Photo: Dan McPhee (DFO)

SHELLFISH: OTHER

TRANSPORTING LIVE SEA SCALLOPS TO QUEBEC'S URBAN MARKETS

YEAR-ROUND SPAWNING AND LARVAL REARING OF GEODUCK (*PANOPEA GENEROSA*) IN CLOSED CULTURE SYSTEM

A MICROALGAL PIGMENT FOR STABILIZING HATCHERY-REARED SEA SCALLOP (*PLACOPECTEN MAGELLANICUS*) PRODUCTION

EARLY DEVELOPMENTAL STAGES OF GEODUCK (*PANOPEA GENEROSA*)

ARE SHELLFISH TRANSFERS A LIKELY VECTOR FOR AQUATIC INVASIVE SPECIES MOVEMENT FROM THE WEST TO THE EAST COAST OF VANCOUVER ISLAND?

THE ECOLOGICAL EFFECTS OF CLAM HARVESTING BY MECHANICAL MEANS IN ST MARY'S BAY, NOVA SCOTIA

UNDERSTANDING THE DISTRIBUTION OF A NEMERTEAN PREDATOR, *CEREBRATULUS LACTEUS*, IN CLAM FLATS: IMPLICATIONS FOR CONTROL MEASURES

QUAHOG (*MERCENARIA MERCENARIA*) SEEDSTOCK PRODUCTION FOR REMOTE SETTING IN NOVA SCOTIA

OCEAN ACIDIFICATION EFFECTS ON SHELLFISH AQUACULTURE

COMPARING CULTURE GEAR AND ADAPTING OFF-SHORE GIANT SEA SCALLOP CULTURE HUSBANDRY TO BAIE DES CHALEUR, NEW BRUNSWICK

DEVELOPING A CARRYING CAPACITY FRAMEWORK FOR BAYNES SOUND, BRITISH COLUMBIA

OPTIMIZING HATCHERY-BASED SEA SCALLOP SETTLEMENT

DETERMINATION OF OPTIMAL MICROALGAL DIETS AND FEEDING RATIONS FOR LARVAE AND SEED OF THE GEODUCK CLAM (*PANOPEA GENEROSA*)

COMPARISON OF MUSCLE REFINING METHODS FOR SEA SCALLOPS (*PLACOPECTEN MAGELLANICUS*) FOR THE LAST TWO YEARS OF FARMING

TRANSPORTING LIVE SEA SCALLOPS TO QUEBEC'S URBAN MARKETS

Sea Scallop (*Placopecten magellanicus*) growers in maritime Quebec have, for many years, sought to market their live product in the urban markets of Québec City and Montreal. Currently, Culti-Mer inc. in les Îles-de-la-Madeleine, sends live scallops by air for sale in these markets. Once they reach distributors, the scallops are kept in cold storage until they are sold. This luxury good is sold live for more freshness and is generally eaten whole. Unfortunately, the short shelf life of live scallops is a limiting factor, to say nothing of the fact that sending them to markets by air depends on often unpredictable weather. The goal is to extend the lifespan of the scallops once they hit the markets in large centres in a similar fashion to live lobster found in restaurants and fish markets. To solve this problem, in 2013–2014, Merinov tested two closed-circuit autonomous holding systems from Nova Scotia-based BioNovations. The performance of these systems was compared to the traditional method used by the company; transport and dry storage in a styrofoam container (cooler). The preliminary results showed that transport in a styrofoam container followed by re-immersion in water is the more promising. Culti-Mer would like Merinov to continue to work to ensure conservation of the organoleptic properties (the aspects of food as experienced by the senses, including taste, sight, smell, and touch) and the safety of the product in the container.

MAY 2013–JUL. 2014

FUNDED BY: Ministère des Finances et de l'Économie du Québec (MFÉ); Fonds d'Amorçage de Partenariat (FAP) (UQAR, Merinov)

PROJECT LEAD: Lisandre Solomon (Merinov)

PROJECT TEAM: Merinov

COLLABORATORS: UQAR; Culti-Mer Inc.; Pec-Nord Inc.

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Sea Scallops. Photo: Jacques Richard

YEAR-ROUND SPAWNING AND LARVAL REARING OF GEODUCK (*PANOPEA GENEROSA*) IN CLOSED CULTURE SYSTEM

Spawning of Geoduck (*Panopea generosa*) in closed culture system. Photo: Jesse Ronquillo (UBC)

This simple and inexpensive closed-culture system for geoduck spawning can be replicated as needed. The portability of the University of British Columbia's (UBC) design of a seawater filtration system can be adopted to prevent microbial contamination during microalgae production and for inducing geoduck broodstock spawning. The developed protocol for inducing broodstock spawning will improve geoduck gamete production and simplify hatchery operations.

Geoduck is the most important commercial shellfish species in British Columbia. Unfortunately, commercial production is limited by the reliable supply of high quality hatchery-produced juveniles. Developing viable and sustainable culture protocols for this species will provide the industry with the needed seedstock to expand production. Benefits from expansion include new economic and employment opportunities for shellfish growers, seafood exporters, and First Nations communities plus a new source of sustainably produced seafood products. The UBC and British Columbia Pacific Oysters, Ltd. (BCPOL) have established a research collaboration to develop sustainable geoduck aquaculture production techniques through NSERC Engage and Engage Plus Grants. The preliminary research outcomes include: (1) design and construction of a prototype closed-culture system for controlled geoduck spawning; (2) fabrication of an elegant yet inexpensive seawater filtration system; (3) successful induction of geoduck broodstock spawning based on environmental manipulation among desiccation, temperature shifts, UV-filtered water stimulation, microalgal addition, and various combinations of the above; and (4) successful development of inexpensive system for efficient and continuous culture of microalgae for feeding geoduck seedstock.

APR. 2014–SEP. 2014

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC) Engage
CO-FUNDED BY: BC Pacific Oyster Ltd. (BCPOL)

PROJECT LEAD: Andrew Riseman (UBC)

PROJECT TEAM: Jesse Ronquillo (UBC)

COLLABORATORS: Tony Farrell (UBC); John Zhang, Daniel McDermid (BCPOL)

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A MICROALGAL PIGMENT FOR STABILIZING HATCHERY-REARED SEA SCALLOP (*PLACOPECTEN MAGELLANICUS*) PRODUCTION

The results of this project provide a natural solution to the issue of massive mortality related to bacterial infections in hatcheries. Use of this technology may improve this industry's yields and productivity.

Sea Scallop (*Placopecten magellanicus*) is a sensitive species and despite recent major developments, spat production is still unstable and primarily affected by the presence of opportunistic pathogenic bacteria of the genus *Vibrio*. These infections cause massive mortalities in tanks and several commercial hatcheries use antibiotics systematically for prevention. However, with the emergence of antibiotic resistant bacteria, this practice is now very controlled and difficult to apply. There is a need for new molecules that possess antibacterial activities and would potentially be meant solely for aquaculture. The micro-alga *Haslea ostrearia*, produced in large volumes at Université de Québec à Rimouski, produces such a molecule. The effectiveness of this pigment, called marennine, for controlling the virulence of the pathogenic bacterium *Vibrio splendidus* and improving the quality of a larval culture of *Mytilus edulis* has already been demonstrated. This project showed that marennine treatment resulted in improvement of the physiological condition and survival of a *P. magellanicus* flow-through larval culture and greatly reduced the virulence of *V. splendidus* in a mortality-causing condition.

AUG. 2014–DEC. 2014

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC) **CO-FUNDED BY:** Ressources Aquatiques Québec (RAQ)

PROJECT LEAD: Réjean Tremblay (UQAR)

PROJECT TEAM: François Turcotte, Jean-Sébastien Deschênes (UQAR)

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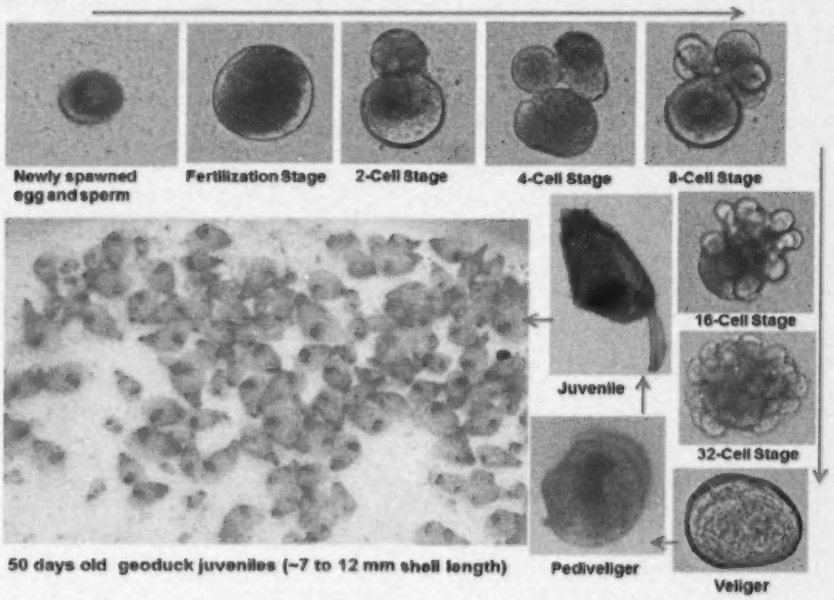
EARLY DEVELOPMENTAL STAGES OF GEODUCK (*PANOPEA GENEROSA*)



Embryonic and post-embryonic stages of geoduck (*Panopea generosa*) under controlled conditions. Photo: Jesse Ronquillo (UBC)

BC Pacific Oysters Ltd. (BCPOL), a Canadian company with a 12.7 hectare grow-out aquaculture facility in Jervis Inlet, British Columbia, has established a partnership with the Faculty of Agriculture, Dalhousie University (formerly Nova Scotia Agricultural College) and the University of British Columbia for the development of a commercial hatchery and seedstock production of geoduck (*Panopea generosa*). The initial research project activities focused on documenting the early embryonic and post-embryonic stages of geoduck to develop a hatchery production protocol. Geoduck broodstock were spawned through natural means and the larvae were reared until early juvenile stage. Primary results showed that after 50 days of culture from spawning, the juveniles reached approximately 7 to 12 mm shell length by feeding on microalgae such as chlorophyte, bacillariophyte, chrysophyte, and prymnesiophyte rich in protein with high level of omega-3 fatty acids. Survival rate was more than 90%, and no disease was found based on juvenile geoduck pathogen analysis conducted at Pacific Biological Station of the Department of Fisheries and Oceans Canada (DFO). The preliminary research results were very promising for the development of a viable commercial geoduck hatchery production system.

The initial results demonstrate the feasibility of developing a viable commercial hatchery production of healthy and good quality geoduck seedstock in Canada to supply the needs of geoduck growers in British Columbia and the United States.

APR. 2009–SEP. 2014

FUNDED BY: BC Pacific Oyster Ltd. (BCPOL)

PROJECT LEAD: Jesse Ronquillo (UBC)

PROJECT TEAM: Audrie-Jo McConkey (Dalhousie U)

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ARE SHELLFISH TRANSFERS A LIKELY VECTOR FOR AQUATIC INVASIVE SPECIES MOVEMENT FROM THE WEST TO THE EAST COAST OF VANCOUVER ISLAND?

The transfer of shellfish (including clams, oysters, and mussels) from areas infested with Non-Indigenous Species (NIS) can be a vector for both mobile and sessile NIS. There are currently no mitigation measures that are 100% effective in removing or destroying NIS on cultured shellfish. The objective of this study was to assess shellfish transfers by the shellfish industry and the Canadian Food Inspection Agency's (CFIA) biotoxin monitoring program as potential vectors for the spread of aquatic invasive species (AIS), with particular focus on the European Green Crab, from the west to the east coast of Vancouver Island. The project quantified the potential risk of AIS introduction associated with current shellfish transfer protocols. Based on the results of the experimental and processor studies, the present conditions of licence do not eliminate the risk of transferring NIS. The gaps identified suggest that the intended reduction in propagule pressure is not being realized under current management/regulatory strategies. A conceptual framework was developed to identify potential control points where management intervention, such as the development of scientifically-based shellfish aquaculture management zones and the application of license conditions could be used to lower propagule pressure and hence invasion risk in British Columbia.

APR. 2011–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Chris Pearce, Hannah Stewart (DFO)

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THE ECOLOGICAL EFFECTS OF CLAM HARVESTING BY MECHANICAL MEANS IN ST MARY'S BAY, NOVA SCOTIA

Traditional hand harvesting is not considered to be a sustainable practice for providing seed for the development of clam aquaculture in Nova Scotia for various reasons, including social and economic factors. The clam aquaculture industry has experienced major challenges in the recruitment and retention of clam diggers, as well as a lack of interest from the younger employable population, resulting in an aging employee-base. Additionally, traditional hand harvesting is very labour-intensive and involves the use of a clam hake, having tines that measure about 15 cm in length, to dig up and turn over the sediment. A mechanical clam harvester has been used in Washington and British Columbia. There is increased interest in utilizing a modified version of this harvester to compliment hand harvesting of quahogs (*Mercenaria mercenaria*) in St Mary's Bay, Nova Scotia. This project will compare the ecological effect of traditional hand harvesting and a mechanical clam harvester. It will investigate the effects of each harvest technique on the ecological health and production of the area through the monitoring of the clam population, associated fauna and flora, and various physical and chemical parameters. Methods for reducing the ecological impact of harvesting, such as replanting pre-recruits on size-class plots and reducing repeated harvesting efforts will also be investigated.

APR. 2012–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Innovative Fisheries Products

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COLLABORATORS: Innovative Fisheries Products

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

UNDERSTANDING THE DISTRIBUTION OF A NEMERTEAN PREDATOR, *CEREBRATULUS LACTEUS*, IN CLAM FLATS: IMPLICATIONS FOR CONTROL MEASURES

The results of this project will provide information to better understand the factors involved in the patchy distribution and abundance of *Cerebratulus lacteus*. This information will aid in the development of efficient management strategies to minimize the effect of this predator on clam populations.

Clams have been identified as an important alternate species for the future development of aquaculture in Atlantic Canada. One of the major obstacles in the development of clam culture has been controlling predators on culture sites, particularly endobenthic species (those that live in the sediment). In recent years, commercial size Quahaug and Soft-Shell Clam densities have reportedly been lower. While the cause for these declines has not yet been documented, harvesters have noted the important presence of predatory worms at clam harvesting sites. The Milky Ribbon Worm, *Cerebratulus lacteus*, is an important predator of many endobenthic bivalve species and its presence has been correlated to high field mortality in Soft-Shell Clams. Very little, however, is known about the factors regulating the patchy distribution of this predator. The present study will examine the factors regulating the patchy distribution and abundance of *C. lacteus* to allow for the development of predator management strategies.

APR. 2014–MAR. 2017

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Innovation Fisheries Products Inc.; Mills Seafood Ltd.

PROJECT LEAD: Daniel Bourque (DFO)

PROJECT TEAM: Angeline LeBlanc (DFO)

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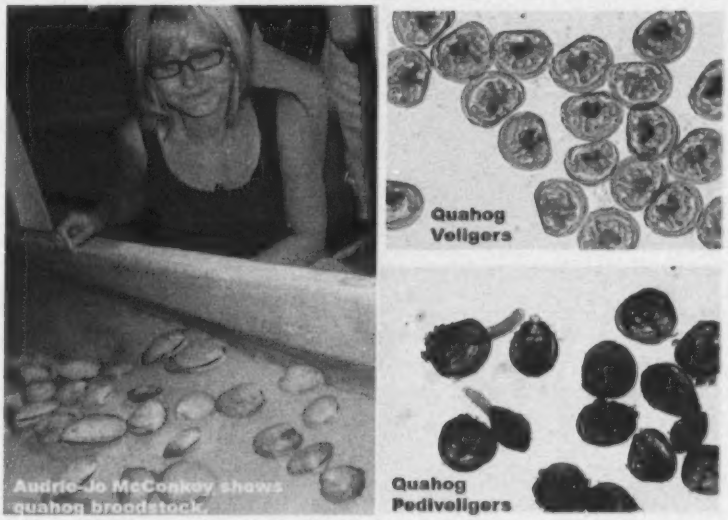
QUAHOG (*MERCENARIA MERCENARIA*) SEEDSTOCK PRODUCTION FOR REMOTE SETTING IN NOVA SCOTIA

Quahog or hard clam (*Mercenaria mercenaria*) is an edible marine bivalve mollusc commonly found along the eastern shores of North America and Central America, ranging from Prince Edward Island to the Yucatán Peninsula. Due to strong market demand, there has been an interest to expand the production of quahogs in the Maritimes. The Gulf Aquaculture Association (GAA), based in Northumberland Strait, requested assistance from Nova Scotia Department of Fisheries and Aquaculture (NSDFA) and the Aquaculture Centre at Dalhousie University to assist the industry to improve quahog production in the province. Jesse Ronquillo (Principal Investigator) and Audrie-Jo McConkey (Shellfish Instructor and Algologist) devised innovative procedures in the spawning and larval rearing of quahog to produce the needed seedstock. Selected species of microalgae rich in highly unsaturated fatty acids (HUFA) were mass-produced continuously in an inventive way to provide abundant and diversified source of live feeds to larvae until they reach pediveliger or eyed-larvae that were used by shellfish growers in Northumberland Strait for remote setting. Over 97 million seedstock were produced in about a month for the grow-out operations of the shellfish growers in Nova Scotia.



Quahog spawning and seedstock production for remote setting. Photo: Jesse Ronquillo (UBC)

The developed protocol for inducing broodstock spawning could improve quahog gamete production and simplify hatchery operations and management. The innovative technique for efficient and inexpensive culture of microalgae can be replicated as needed to improve commercial shellfish hatchery production and operations.

MAR. 2012–OCT. 2012

FUNDED BY: Nova Scotia Department of Fisheries and Aquaculture (NSDFA) **CO-FUNDED BY:** Gulf Aquaculture Association (GAA)

PROJECT LEAD: Jesse Ronquillo (UBC)

PROJECT TEAM: Audrie-Jo McConkey (Dalhousie U)

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OCEAN ACIDIFICATION EFFECTS ON SHELLFISH AQUACULTURE

Rising atmospheric CO_2 levels increases pCO_2 in seawater, lowering the pH and causing ocean acidification which can profoundly affect shellfish aquaculture. Surface pCO_2 can also rise in coastal regions due to the upwelling of deep, ancient water. While pCO_2 levels are anticipated to rise consistently in the greater ocean due to elevated atmospheric CO_2, coastal upwelling regions are already experiencing dramatic fluctuations in pCO_2 that encompass the upper limits expected in the greater ocean in over 100 years' time. Coincident with observations of enhanced pCO_2 variation and potentially a higher average pCO_2 experience along the BC and Washington State coastlines has been dramatic failures of shellfish aquaculture production both in the hatcheries and in ocean grow-out sites. This project was undertaken to begin collecting data and information in support of a causal link between reduced industry performance and pCO_2, as well as to identify vulnerable developmental stages and physiologies.

A clear signature of development was observed in the microarray data for both scallops and oysters. However, while there appeared to be a negative growth response to elevated pCO_2 during some time periods, there was no consistent gene expression pattern differentiating treatments in the microarray data. However, it was found that there may be some level of acclimation possible, i.e., individuals that survive adverse conditions as larvae will perform better under those conditions as juveniles. This may point to an alternate larval rearing strategy that may benefit industry through the rearing of larvae under sub-lethal adverse conditions and selecting the most robust for settling and ocean ranching.

APR. 2011–JUL. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Island Scallops; Island Sea Farms Inc.; Taylor Shellfish Farms Canada; Limberis Seafoods Ltd.; Odyssey Shellfish Ltd.; Kyuquot Seafoods Ltd.

PROJECT LEAD: Kristi Miller-Saunders (DFO)

COLLABORATORS: Island Scallops, Island Sea Farms Inc.; Taylor Shellfish Farms Canada; Limberis Seafoods Ltd.; Odyssey Shellfish Ltd.; Kyuquot Seafoods Ltd.

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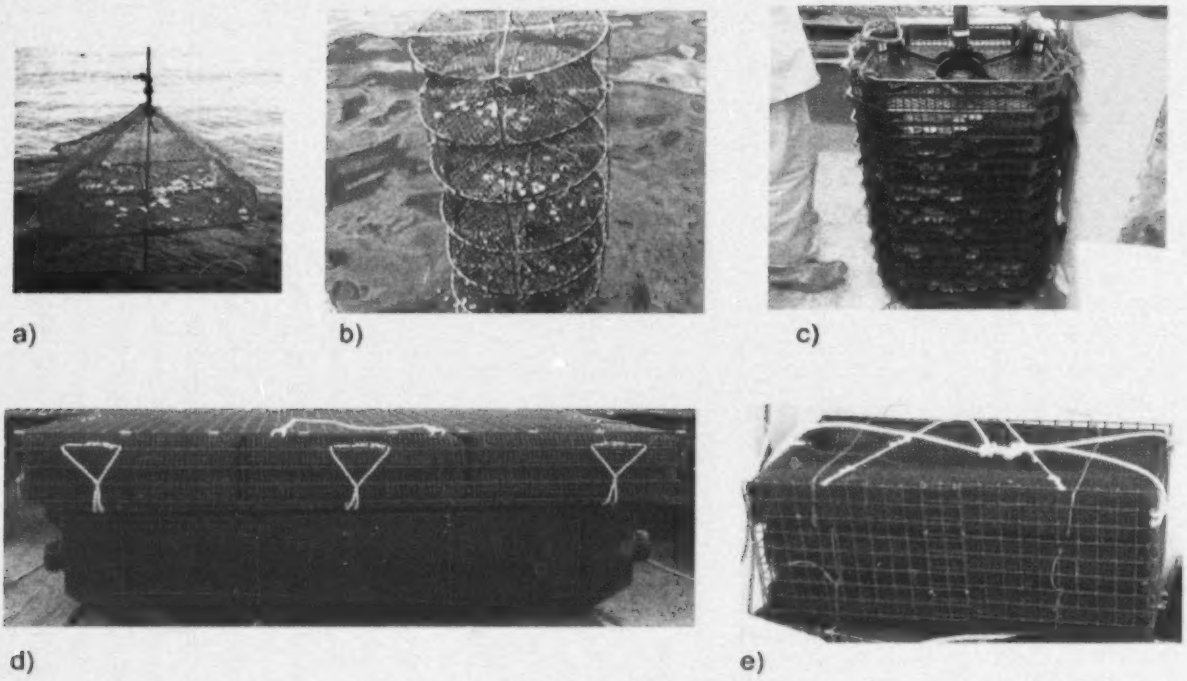
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

COMPARING CULTURE GEAR AND ADAPTING OFF-SHORE GIANT SEA SCALLOP CULTURE HUSBANDRY TO BAIE DES CHALEUR, NEW BRUNSWICK



Scallop culture gear showing a) Pearl net, b) Lantern net, c) Dark Sea trays, d) OysterGro® culture system with bottom floats, and e) Kenny cabin. Photo: Leslie-Anne Davidson (DFO)

The availability of culture sites can be a limiting factor for the expansion of aquaculture in Canada. Up until 2014, most shellfish culture leases have been located in protected bays. However, in the Gulf Region, lease area in protected bays is limited. More importantly, the environmental factors (such as temperature) in protected bays are not suitable for shellfish like the Giant Sea Scallop (*Placopecten magellanicus*). This project assessed the growth and survival of Giant Sea Scallops cultured in an exposed environment (an offshore site in Baie des Chaleurs). Furthermore, the following five types of culture gear were tested in suspension to determine which gear best minimized scallop morality rates and promoted optimal growth rates: Pearl nets, Lantern nets, Dark Sea trays, OysterGro®, and Kenny cabins. In addition, scallops were also placed in OysterGro® on the bottom.

Results showed that scallops grown in suspension for two years had the highest growth rates except for those that were in heavily fouled gear. The gear with the best performance in terms of scallop growth rate and survival (0.078 ± 0.015 mm/day and 99.2%, respectively) was the Kenny cabin. Scallops grown in Lantern nets, which are the traditional culture gear, exhibited the highest growth rate (0.079 ±0.019 mm/day) but had the lowest survival (77.2 %).

Measuring scallops using electronic calipers that register data directly in an Excel file. Photo: Leslie-Anne Davidson (DFO)

The results of this study have provided the information required to evaluate the potential to culture scallops offshore in Baie des Chaleurs and sustainably expand the shellfish aquaculture industry in this area. Based on the growth rates, survival, and spat collection rates observed in this study, farming sea scallop in an exposed environment is feasible.

APR. 2010 – MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Kenny Aquaculture

PROJECT LEAD: Leslie-Anne Davidson (DFO)

COLLABORATORS: Kenny Aquaculture

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

DEVELOPING A CARRYING CAPACITY FRAMEWORK FOR BAYNES SOUND, BRITISH COLUMBIA

Shellfish aquaculture is an important activity in coastal environments. Successful culture of suspension-feeding shellfish relies heavily on the supply of phytoplankton food which is mainly controlled by hydrodynamic factors in estuaries with strong gradients in flushing characteristics (e.g., Baynes Sound, Strait of Georgia, B.C.). Large cultured bivalve populations may potentially deplete particles from the water column much faster than flushing or phytoplankton production can renew them on a local scale (farm depletion). Although re-suspension events or organic-rich sediments may provide a buffer against a fluctuating planktonic food supply, areas prone to re-suspension of silt-laden flocs may shutdown feeding of shellfish. The main objective of this project is to develop a carrying capacity model for shellfish production in Baynes Sound. The project will focus on establishing a particulate budget for the Sound and providing a real-time assessment of the current state of benthic and pelagic conditions in support of the development of siting criteria. Longer term goals involve developing circulation and nutrient models that describe the hydrodynamic and biological controls on particulate concentrations in Baynes Sound. These models will be coupled with shellfish assimilative estimates to determine the influence of shellfish production on benthic and water column quality.

APR. 2011 – MAR. 2015

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Terri Sutherland (DFO)

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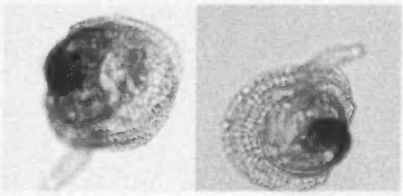
OPTIMIZING HATCHERY-BASED SEA SCALLOP SETTLEMENT

During the life cycle of bivalves, larvae transition from the pelagic (water-column) stages to benthic life via settlement and metamorphosis (physical development). Settlement is a significant limiting factor in the success of scallop hatcheries. Although settlement success in some larval cultures can reach up to 80% in good conditions, larval settlement and metamorphosis success rarely exceed 25 to 30%. Metamorphosis in bivalves is accompanied by the loss of their larval food collection system (velum) and the development of gills (adult food collection system). This period is critical given the larvae's limited ability to feed while undergoing metamorphosis, and in order for metamorphosis to be successful, this change must be completed rapidly. Competent larvae will settle and undergo metamorphosis under the influence of various chemical, physical, and biological signals that are still unknown for Sea Scallops. This project aimed to increase settlement/metamorphosis success while reducing the time required to produce competent larvae.

Sea Scallops were successfully cultured in the production systems and this research has shown that it is possible to substantially increase settlement and metamorphosis success. By adjusting the hydrodynamic conditions of the production systems, it is possible to substantially increase settlement and metamorphosis success, the lack of which has been a major reason for losses in scallop hatcheries.



Juvenile post-larval sea scallop, *Placopecten magellanicus*. Photo: Réjean Tremblay (UQAR)

APR. 2010–OCT. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Institut des Sciences de la Mer (ISMER); Société de Développement de l'Industrie Maricole (SODIM)

PROJECT LEAD: Jean-Marie Sévigny (DFO)

PROJECT TEAM: Réjean Tremblay (Institute des Sciences de la Mer de Rimouski)

COLLABORATORS: Institut des Sciences de la Mer (ISMER); Société de Développement de l'Industrie Maricole (SODIM)

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DETERMINATION OF OPTIMAL MICROALGAL DIETS AND FEEDING RATIONS FOR LARVAE AND SEED OF THE GEODUCK CLAM (*PANOPEA GENEROSA*)

Juvenile geoduck clams. Photo: Chris Pearce (DFO)

The geoduck clam aquaculture industry has been constrained by the lack of a reliable seed supply (due to very high larval mortality), indicating significant problems with the current hatchery production strategies. In order to establish hatchery-rearing protocols of a cultured bivalve species, it is necessary to examine a number of biotic and abiotic factors, such as temperature, diet quality, and diet quantity. This research aimed to determine optimal temperature, microalgal diets, and feeding rations for *P. generosa* larvae and seed.

Optimum microalgal diets were identified for larval and young juvenile geoduck clams. Optimum temperature and rations were identified for various size classes of young juvenile clams. These results will improve the reliability and production capacity of geoduck hatcheries in British Columbia and will help alleviate the hatchery bottleneck in the culture of geoduck clams. With improved hatchery knowledge, the aquaculture industry will be able to produce more geoduck seed (and more reliably) for outplanting.

AUG. 2010–OCT. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Klahoose Shellfish Limited Partnership

PROJECT LEAD: Chris Pearce (DFO)

PROJECT TEAM: Wenshan Liu, Ian Forster (DFO); Scott McKinley, Bianca Arney (UBC); Yichao Ren (Key Laboratory of Mariculture, Ministry of Education, Ocean University of China, Qingdao, China)

COLLABORATORS: Klahoose Shellfish Limited Partnership

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

COMPARISON OF MUSCLE REFINING METHODS FOR SEA SCALLOPS (*PLACOPECTEN MAGELLANICUS*) FOR THE LAST TWO YEARS OF FARMING

Quebec scallop producers prefer suspension farming for growing Sea Scallop spat. This stage of production is conducted in pocket nets, lantern nets, or ear-hanging bags. Some previous studies have shown that using ear-hanging bags during the last two years yielded Sea Scallops with more muscle than pocket nets or lantern nets. However, scallops grown with ear-hanging bags are prone to significant biofouling that affect their survival and handling. The industry wants to have a production scenario that limits the biofouling while producing good quality muscle.

This project will provide biological data that Sea Scallop producers can use to optimize their production strategy. The project aims to evaluate Sea Scallop muscle refining scenarios. The specific objectives are to: 1) compare the yield in muscle of scallops grown using ear-hanging bags after two years with that of scallops grown using ear-hanging bags after one year; 2) document the effect of the density of scallops grown in lantern nets on muscle yield for two years; 3) document the effect of scallop position (lantern nets vs. ear-hanging bags) on muscle yield and activity; and 4) carry out a technical-economic analysis of selected production scenarios.

This project will generate useful data for scallop producers in order to optimize their production strategies.

Filtration rate for scallops kept in a horizontal position (left) and in a vertical position (right). Photo: Carole Cyr (Merinov)

NOV. 2012 – DEC. 2015

FUNDED BY: MAPAQ

LEAD: Carole Cyr (Merinov)

PROJECT TEAM: Lisandre G. Solomon, Madeleine Nadeau (Merinov)

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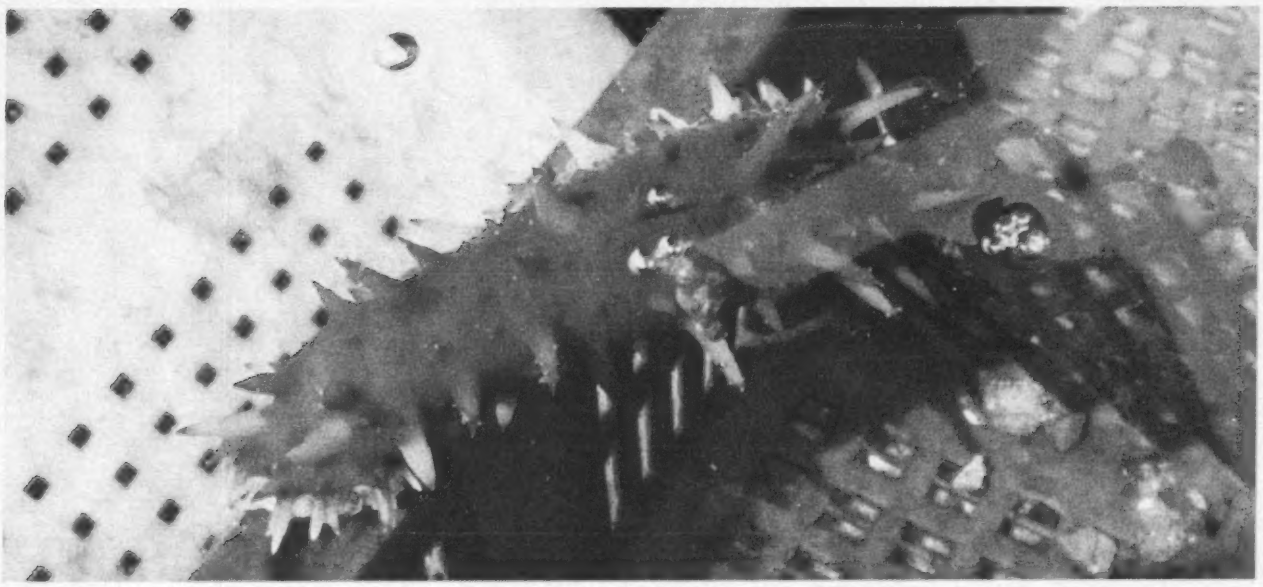

Sea cucumber (*Parastichopus californicus*) in tank at the DFO Pacific Biological Station. Photo: Emily Nelson

MISCELLANEOUS

- PHYSIOLOGY OF TRIPLOID FISH
- FISH-KELP CO-CULTURE: A FEASIBILITY STUDY FOR THE COMMERCIAL SCALE INTEGRATION OF KELP CULTURE WITH FINFISH PRODUCTION IN COASTAL BRITISH COLUMBIA
- HIGHER TROPHIC LEVEL RESPONSES TO SHELLFISH AQUACULTURE HABITAT MODIFICATIONS
- THE FARMS OF OPPORTUNITY PROGRAM–AN INTEGRATED WATER QUALITY MONITORING AND MANAGEMENT NETWORK FOR COASTAL AQUACULTURE
- BRINGING THE FARM TO THE CITY: AN INTERACTVE LIVE VIDEO PLATFORM FOR PUBLIC AWARENESS AND EDUCATION INITIATIVES
- TECHNICAL, ECONOMIC, AND REGULATORY GUIDES FOR PART TIME MARINE AQUACULTURE FISHERS IN THE ÎLES DE LA MADELEINE AND THE GASPÉ PENINSULA
- INTEGRATION OF A GENETIC SEX MARKER INTO BREEDING PROGRAMS TO PRODUCE SINGLE-SEX POPULATIONS OF FISH
- CERES: A RELATIONAL DATABASE MANAGEMENT PROGRAM
- THE HISTORICAL AND SOCIAL DIMENSIONS OF SALMON AQUACULTURE SCIENCE
- PHYSIOLOGICAL INDICES AS INDICATORS OF ECOSYSTEM STATUS IN SHELLFISH AQUACULTURE SITES
- OMEGA-3 FATTY ACIDS FROM SALMON PROCESSING WASTE PRODUCED FROM NEWFOUNDLAND AQUACULTURE INDUSTRY
- WAVE POWERED LAND-BASED INTERGRATED MULTITROPHIC AQUACULTURE
- USE OF THE OILSEED *CAMELINA SATIVA* AS A SOURCE OF LIPID AND PROTEIN IN DIETS FOR RAINBOW TROUT, ATLANTIC SALMON, AND ATLANTIC COD
- RESILIENCE OF COASTAL ECOSYSTEMS TO GREEN CRAB INTRODUCTION AND REMOVAL
- CAPTURING SOCIAL VALUES IN OCEAN MANAGEMENT AND PLANNING: NEW TOOLS FOR NEW TIMES
- DEVELOPMENT OF DIET AND FEEDING REGIMES FOR COPPER ROCKFISH LARVAE
- SHELLFISH MICROBIAL ELIMINATION THROUGH THE AQUALIFE FACILITY
- CENTER FOR AQUACULTURE TECHNOLOGIES CANADA AQUACULTURE RESEARCH FACILITY
- OPTIMAL PROGRAM: LAYING THE GROUNDWORK FOR AN INTEGRATED APPROACH TO DEVELOPING THE CULTURED ALGAE INDUSTRY IN QUEBEC
- UTILIZING ALTERNATE WAVELENGTHS TO INCREASE LEVELS OF THE OMEGA-6 ARACHIDONIC ACID (ARA) IN MICROALGAE
- IDENTIFYING CRITICAL ECOLOGICAL THRESHOLDS FOR TUNICATE INFESTATIONS ON MUSSEL FARMS
- ASSESSING THE EFFICIENCY OF A MACROALGAE BIOFILTER IN REGULATING NITRATE AND PHOSPHATE CONCENTRATIONS IN TANKS AT THE MONTRÉAL BIODÔME, IMITATING THE ECOSYSTEM OF THE GULF OF ST. LAWRENCE
- ANAEROBIC DIGESTION OF FISH OFFAL AND SAWDUST
- ESTABLISHING AN ECOTOXICOLOGY WET LAB TO COLLECT NON-TARGET THERAPEUTANT DATA FOR PHARMACEUTICAL COMPANIES AND REGULATORS
- BENTHIC CULTURE OF SEA CUCUMBERS: ASSESSING INTERACTIONS BETWEEN CULTURED AND WILD POPULATIONS AND THE MITIGATION OF ENVIRONMENTAL IMPACTS IN SHELLFISH CO-CULTURE
- ISOLATION, CULTURE, AND GENOMIC ANALYSIS OF HARMFUL ALGAL SPECIES AFFECTING AQUACULTURE ON THE WEST COAST OF CANADA AND ANALYSIS OF THE HARMFUL ALGAE MONITORING PROGRAM HISTORICAL DATABASE
- INNOVATIVE APPROACHES TO WATER TREATMENT FOR LAND BASED FISH FARMS FOR RECIRCULTION AND DISCHARGE

PHYSIOLOGY OF TRIPLOID FISH

Understanding the physiological limitations of triploidy will allow for improvements in their culture protocols for commercial production. This will benefit the aquaculture industry in two ways: by eliminating early maturation of production fish and by ensuring that escaped fish cannot breed in the wild.

Triploidy is the only management tool currently available for ensuring reproductive sterility of farmed fish. Sterile populations can be of direct benefit to industry, since sexually mature fish often have reduced flesh quality and poor disease resistance. Sterility also addresses the risk of escaped fish breeding in the wild. However, triploids are rarely used in aquaculture because of performance limitations. We are investigating the effects of triploidy on key physiological processes to determine whether changes in cell size and number associated with triploidy affect the ability of these animals to withstand chronic stress. Our research currently focuses on red blood cell structure and function, aerobic capacity, bioenergetics and environmental tolerances. We have adopted Zebrafish as a model species for some of this research due to the availability of stocks with fluorescent cells that are ideal biomarkers for cell location and function. Additional research is being done with Brook Charr, as a model salmonid that is easy to keep in our small-scale aquatic facility at the UNB campus. Research results will be extended to Atlantic Salmon.

ONGOING

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC) Discovery

PROJECT LEAD: Tillmann Benfey (UNB)

PROJECT TEAM: Chris Small, Nicole Nader, Kathleen O'Donnell (UNB)

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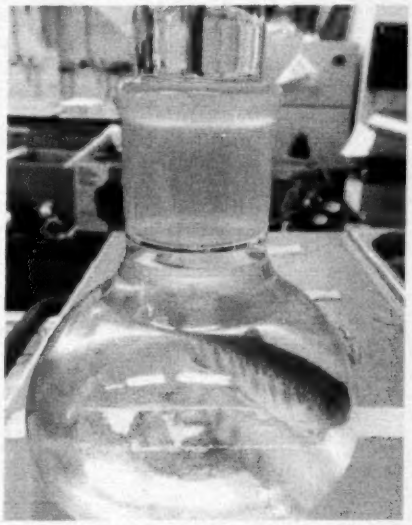
www2.unb.ca/biology/Faculty/Benfey.html



Juvenile Brook Charr in a respirometer used for measuring oxygen consumption. Photo: Kathleen O'Donnell (UNB)

FISH-KELP CO-CULTURE: A FEASIBILITY STUDY FOR THE COMMERCIAL SCALE INTEGRATION OF KELP CULTURE WITH FINFISH PRODUCTION IN COASTAL BRITISH COLUMBIA

Seeded spool with 50 metres of *Saccharina latissima* ready to deploy. Photo: Stephen Cross (NIC-CARTI)

This research will provide a detailed technical and socio-economic assessment for the development of a kelp aquaculture sector in coastal British Columbia.

This project critically evaluates the commerical-scale production potential for *Laminaria* kelps adjacent to the fish farm facilities in coastal British Columbia. Historical water quality data and performance trails at 15 farm sites will be used to assess growth rates, tissue quality, and annual extrapolated production capacity among the farm sites given available tenure space. The analysis will include production capacity, product positioning and markets, product value, capital and operating costs, secondary industry support requirements, staffing and training needs, business models, and sector growth potential. Initial (Year 1) farm trial results indicated a 38% enhanced growth of kelp cultured within the nutrient plume downstream of a fish farm, supporting the anticipated and additional benefits of environmental impact mitigation using this basic, Intergated Bi-Trophic Aquaculture approach.

JUL. 2013–JUN. 2018

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC)

PROJECT LEAD: Stephen Cross (NIC – CARTI)

PROJECT TEAM: Nicholas Sherrington (UVic)

COLLABORATORS: Creative Salmon; Marine Harvest Canada; Grieg Seafood; Cermaq; SEA Vision Group

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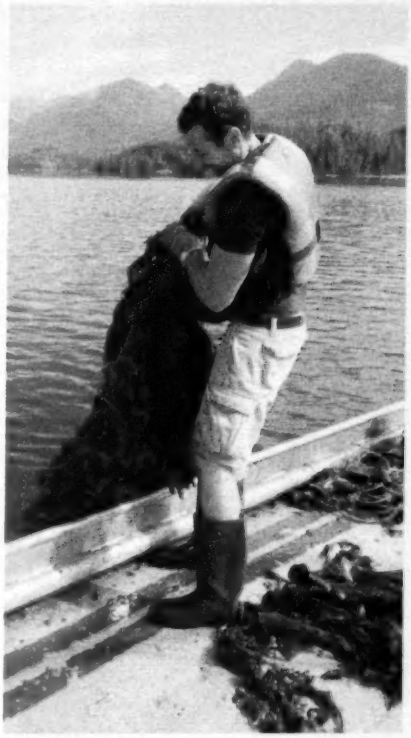


Nick Sherrington pulling a vertical kelp line at Creative Salmon farm site. Photo: Stephen Cross (NIC – CARTI)

HIGHER TROPHIC LEVEL RESPONSES TO SHELLFISH AQUACULTURE HABITAT MODIFICATIONS

These findings will indicate how, and to what extent, juvenile salmonids and intertidal fish are utilizing shellfish aquaculture structures as habitat with potential implications for shellfish aquaculture practices and regulations. They will also provide information on the potential value of shellfish aquaculture structures as rearing and feeding habitats for juvenile Pacific salmon in this region.

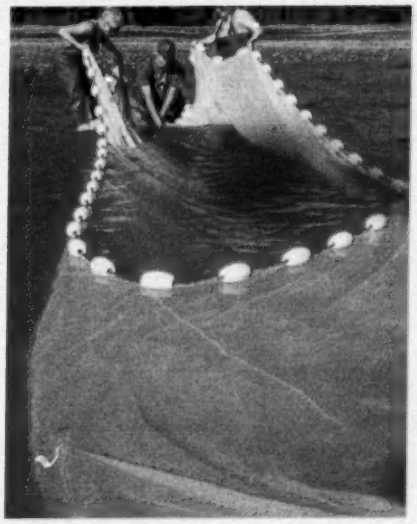
Intertidal shellfish farms are prominent on the shoreline of Baynes Sound, British Columbia. In this region, approximately 50% of Manila Clams and 30% of Pacific Oysters produced by the province are grown. Additionally, many rivers and streams run into this area, providing valuable Pacific salmon spawning habitat from which juvenile salmon then emerge and use the nearshore areas to feed and grow. The goal of this project is to determine the habitat value of intertidal shellfish aquaculture tenures for juvenile salmonids and intertidal fish communities. During the spring/summer of 2014, juvenile salmonids and intertidal fish were sampled at shellfish leases and nearby reference sites. Fish species, abundance, and stomach contents will be analyzed for spatial and temporal trends. Site attributes such as habitat complexity and vegetation will also be investigated. Fish community parameters to be compared include, juvenile/adult ratio, species diversity and richness, body size by species, and functional diversity. Functional diversity is essentially a measure of ecosystem integrity based on the characteristics of the individuals found in the selected habitat. Given the increased shoreline complexity associated with shellfish aquaculture, we expect shellfish tenures to provide significant habitat value to fish.

SEP. 2013–AUG. 2015

FUNDED BY: Canada Research Chairs Program
CO-FUNDED BY: Canada Foundation for Innovation; British Columbia Knowledge Development Fund; Vancouver Island University; University of Victoria, Natural Sciences and Engineering Research Council (NSERC)

PROJECT LEAD: Sarah Dudas (VIU)

PROJECT TEAM: Robert Bourdon, Brenna Collicutt (UVic, VIU); Katie Davidson (VIU)



Graduate students, Brenna Collicutt and Robert Bourdon, and undergraduate, NSERC USRA student Katie Davidson, beach seining at a shellfish aquaculture lease in Baynes Sound, BC. Photo: Lorne Collicutt

COLLABORATORS: Francis Juanes (UVic)
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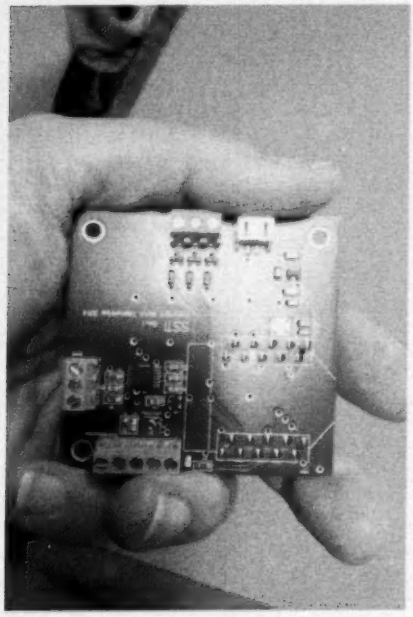
THE FARMS OF OPPORTUNITY PROGRAM – AN INTEGRATED WATER QUALITY MONITORING AND MANAGEMENT NETWORK FOR COASTAL AQUACULTURE



Custom computer board designed to control winch profiler, multiple water quality sensor array, and system telemetry. Photo: Steve Morgan

Development of an autonomous water quality monitoring network will result in the collection and compilation of valuable spatial and temporal data that will be able to support aquatic animal health assessments as well as regional issues that may arise as a result of coastal climate change.

In the 1970's, DFO Science initiated a program that opportunistically gathered open ocean data by placing instrumentation in the bows of freighters that routinely travelled between Asia and Vancouver – the Ships of Opportunity Program (SOP). With todays rapidly changing climate, the impacts to our oceans and specifically to our coastal waters may have serious implications to aquaculture production. Using the SOP concept, this project is developing a Farms of Opportunity Program that will collect consistent, high-quality water quality information from a network of farm sites located at selected (if not all) aquaculture farm sites in coastal British Columbia. The project team is designing a web-controlled (programmable) water quality profiling station that can be secured at an optimal location on each farm. Powered by solar energy, the individual stations will be linked, via a localized telemetry network, to a single regional base station that will relay data to/from a central data archive and management platform using satellite or cellular protocols. The project is developing and testing system and network components (hardware and software) at four farm sites as a demonstration initiatitve.

JUL. 2013–JUN. 2018

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC)

PROJECT LEAD: Stephen Cross (NIC – CARTI)

PROJECT TEAM: Steve Morgan (Island Telemetrics)

COLLABORATORS: Creative Salmon; Marine Harvest Canada; Grieg Seafood; Cermaq; SEA Vision Group; Island Telemetrics

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http://www.nic.bc.ca/research

BRINGING THE FARM TO THE CITY: AN INTERACTVE LIVE VIDEO PLATFORM FOR PUBLIC AWARENESS AND EDUCATION INITIATIVES

Development of an interactive, live video feed that supports public education for aquaculture represents an important social aspect for the sustainable development and growth of the sector in Canada. These tools will also be valuable to ongoing curriculum development in the classroom... from high school through university.

Operating, for the most part, in remote coastal locations, particularly in British Columbia, the general public has little opportunity to visit and understand how aquaculture facilities work. In an effort to make aquaculture accessible, a web-based viewing platform is being developed to allow user control (web-based interface) of remote cameras situated in a cross-section of locations across industry – both above and below water. We will trial these systems for use in the classroom (North Island College, University of Victoria), and as "interactive" features in long term aquaculture displays such as those developed in the Comox Valley Visitors Centre, the Ucluelet Aquarium, the Campbell River Discovery Passage Aquarium, and the Vancouver Public Aquarium. The attraction of a "joystick" that allows camera movement, including deployment into a cage of fish and along the outer edge of a stack of oyster trays, will engage a public that generally has a limited perception of what aquaculture is all about. If a picture is worth a thousand words then a live video feed can only be considered "priceless".

Traditional static displays of aquaculture (salmon, shellfish) as shown at Comox Valley Visitor Centre. Photo: Stephen Cross (NIC)

JUL. 2013–JUN. 2018

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC)

PROJECT LEAD: Stephen Cross (NIC – CARTI)

PROJECT TEAM: NIC- Remote Web-Based Science Laboratory (RWSL)

COLLABORATORS: SEA Vision Group; Odyssey Shellfish; Creative Salmon; Marine Harvest Canada; Grieg Seafood; Cermaq

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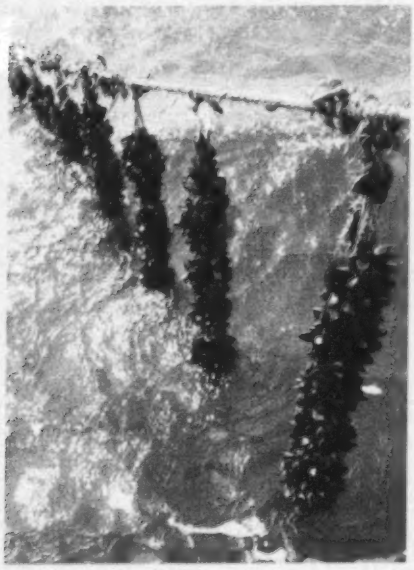
TECHNICAL, ECONOMIC, AND REGULATORY GUIDES FOR PART-TIME MARINE AQUACULTURE FISHERS IN THE ÎLES DE LA MADELEINE AND THE GASPÉ PENINSULA



Traditional Blue Mussel socks.

The purpose of this tool is to set up new marine aquaculture enterprises in the maritime regions of Quebec and to increase marine aquaculture production volume for these areas. The fishery is a major economic resource for maritime regions of Quebec and it is currently facing challenges that can harm its profitability. In this sense, the fishery needs to be consolidated and in parallel, aquaculture is an economically viable activity that is developing in the same areas.

The objective of this project is to create a technical-economic tool to add to the business plans of fishers who want to culture scallops and mussels in the Gaspé Peninsula and les Îles-de-la-Madeleine. The primary goal is to determine best production scenarios through a comparative technical-financial feasibility analysis. Production costs and additional investments will be assessed by setting reasonable production volumes to complement the traditional fishing activities by marine aquaculture. Our goal is to implement business models that differ from the models currently in place where most marine aquaculture enterprises look after collecting spat until the final marketing stage. The project is focused on the culture grow-out aspect.

APR. 2014–MAR. 2015

FUNDED BY: Ministère de l'Économie, de l'Innovation et de l'Exportation du Québec
CO-FUNDED BY: Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec

PROJECT LEAD: Jean-François LaPlante (Merinov)

PROJECT TEAM: Estelle Pedneault, François Bourque, Claude Forest

COLLABORATORS: Regroupement des pêcheurs propriétaires du sud de la Gaspésie; Culti-Mer; Grande-Entrée Aquaculture; Moules de culture des Îles

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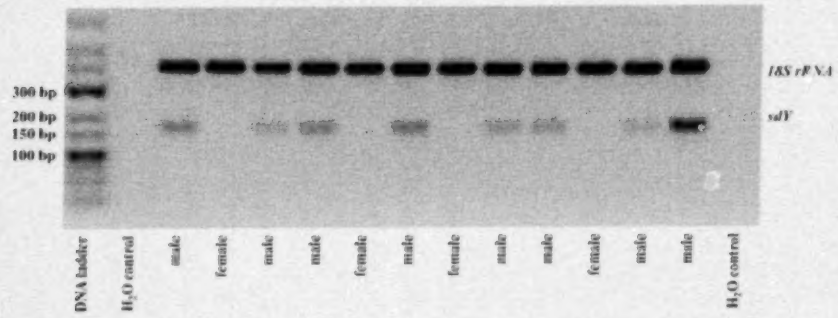
INTEGRATION OF A GENETIC SEX MARKER INTO BREEDING PROGRAMS TO PRODUCE SINGLE-SEX POPULATIONS OF FISH



PCR amplification of sdY and a control locus (18S rRNA) from male and female Brook Charr. Photo: Center for Aquaculture Technologies Canada

The use of a genetic marker for sex will greatly facilitate the production of all-female populations of fish, whether for use as fertile diploids or sterile triploids.

In many species of fish, all-female populations can be produced by crossing functionally masculinized genetic females ('neomales') with normal females. This approach is hampered by the difficulty of distinguishing neomales from normal males. The aim of this project was to demonstrate how a Rainbow Trout sex-determining gene (sdY) can be used to identify neomales in other species of fish, using Brook Charr as a model. DNA was collected from 25 adults and coded to disguise their sex. Using traditional end-point PCR to check for the presence or absence of sdY, all fish were assigned to the correct sex. The same test was then performed on a population of fish exhibiting typical male secondary sexual characteristics following androgen treatment during early development, and separate families created from males confirmed to possess the sdY marker and males confirmed to lack the marker. All families sired by males possessing the sdY marker had sex ratios not significantly different from 1:1, whereas all fish sired by males lacking the sdY marker were females, thus confirming that the Rainbow Trout sdY marker can be used to identify neomales in other salmonid species for the sake of integrating them into breeding programs to generate all-female populations.

SEP. 2013–MAY 2014

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC) Partnerships Program – Engage Grant

PROJECT LEAD: Tilmann Benfey (UNB)

PROJECT TEAM: Debbie Plouffe, Matthew Bryenton (CATC)

COLLABORATORS: Center for Aquaculture Technologies Canada (CATC)

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CERES: A RELATIONAL DATABASE MANAGEMENT PROGRAM

A relational database management program decreases opportunity for human error, provides a secure location for data storage, and reduces time to analysis by storing all data together while facilitating simultaneous export for analysis in external statistical programs or reporting purposes. Ceres also provides quality control, quality assurance, and auditing capability (key features when working towards traceability).

Large-scale, multi-year research programs tend to collect volumes of data that can be difficult to manage to allow timely and effective analysis and decision-making. Ceres was developed as a relational database management program that tracks individual fish and families over innumerable measurements/challenges from egg to plate. The Main Application exists on a secure server to hold all data from various types of sampling efforts. Flexibility is provided to the Data Manager by creating data collection specific forms. The Disconnected Application facilitates data entry from any remote location. Created data files are encrypted on export and uploaded to the Main Application where Quality Control is performed prior to transfer. Changes to data entries are recorded and available for Quality Assurance. The Main Application allows technical staff viewing with no data manipulation capability. Additional features include: uploading of archived data as .csv or tab delimited text files, real time calculation with alerts to signal if data entered are out of range, counts (e.g., count number of fish per treatment/tank), autofill (e.g., family identification while PIT tagging), auto-increment (e.g., individual fish numbering), direct scanning from PIT tag readers, and ability to export data directly into different formats (Excel, .csv, .pdf) while entering data.

OCT. 2011–SEP. 2015

FUNDED BY: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund (ACOA-AIF) **CO-FUNDED BY:** New Brunswick Innovation Foundation; Huntsman Marine Science Centre; Aqua Bounty Canada; Center for Aquaculture Technologies – Canada (CATC)

PROJECT LEAD: Amber Garber (Huntsman Marine Science Centre)

PROJECT TEAM: Gilbert Babin, Susan Hodkinson, Chris Bridger (Huntsman Marine Science Centre)

COLLABORATORS: Dawn Runighan (Aqua Bounty Canada); Debbie Plouffe (CATC)

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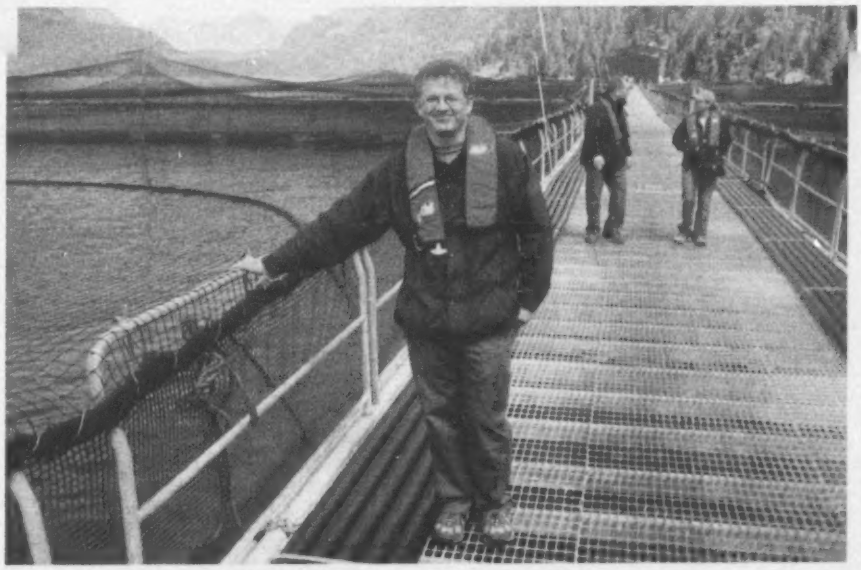
THE HISTORICAL AND SOCIAL DIMENSIONS OF SALMON AQUACULTURE SCIENCE

This project is providing a better understanding of how salmon aquaculture science has developed in relation to the growth of the industry in its varied environmental and social contexts.

Salmon aquaculture has been a focus of environmental research for over two decades. In this project I am applying the tools of environmental history and science and technology studies to understand how this research has developed and the roles it has played in public discussions regarding the industry. Several more specific objectives are also being pursued. First, I am writing an environmental history of salmon aquaculture science. This history will explore the relations between scientific research and the evolving environmental, social, and political dimensions of the industry. Second, I am examining how the diverse institutions engaged in environmental research (e.g., governments, universities, industry, and public interest organizations) have shaped research priorities, research results, and the application of these results. Third, I am investigating the movement of scientific knowledge of salmon aquaculture between research sites in Canada, Norway, Ireland, and Scotland. Fourth, I am examining the prospects for effective science, that is able to contribute to resolution of controversies regarding this industry. While this project is examining the full range of environmental science relating to salmon aquaculture, a special focus is on research relating to sea lice.



Salmon farm near Campbell River, British Columbia. Photo: Stephen Bocking (Trent U)

JUN. 2007–JUL. 2016

FUNDED BY: Social Sciences and Humanities Research Council of Canada (SSHRC)

PROJECT LEAD: Stephen Bocking

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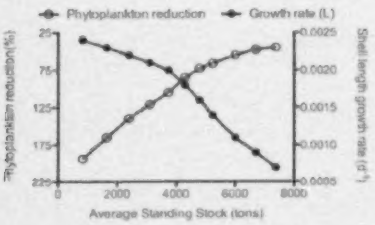
PHYSIOLOGICAL INDICES AS INDICATORS OF ECOSYSTEM STATUS IN SHELLFISH AQUACULTURE SITES

The purpose of this project was to assess three bivalve physiological indices as potential indicators of ecosystem status: (1) condition index (*static*); (2) tissue mass growth rate (*dynamic*); and (3) shell length growth rate (*dynamic*). Ecosystem status in shellfish aquaculture sites has been commonly studied using the well-known concept of carrying capacity. Given the potential top-down pressure that bivalves can exert on phytoplankton populations and the role of phytoplankton as the base of the trophic web, carrying capacity determinations typically use phytoplankton concentration as a benchmark. Our underlying premise was that there is an inherent feedback mechanism in shellfish farming, one that reduces growth performance due to food depletion when shellfish are over-stocked within a system. A modelling exercise carried out in Tracadie Bay, PEI, showed significant relationships among phytoplankton abundance and the three tested physiological indices. It demonstrated the potentiality of using bivalve physiological measurements in monitoring programs as indicators of ecosystem status. The model suggested that shell length growth rate is the most sensitive indicator of phytoplankton abundance, followed by tissue mass growth rate and then condition index.



Median bay-scale phytoplankton reduction (%) and shell length growth rate (1/d) in different standing stock biomass scenarios. Image: Ramón Filgueira (DFO)

APR. 2011–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Ramón Filgueira (DFO)

PROJECT TEAM: Luc Comeau, Thomas Guyondet (DFO)

COLLABORATORS: Thomas Landry (DFO); Jonathan Grant (Dalhousie U)

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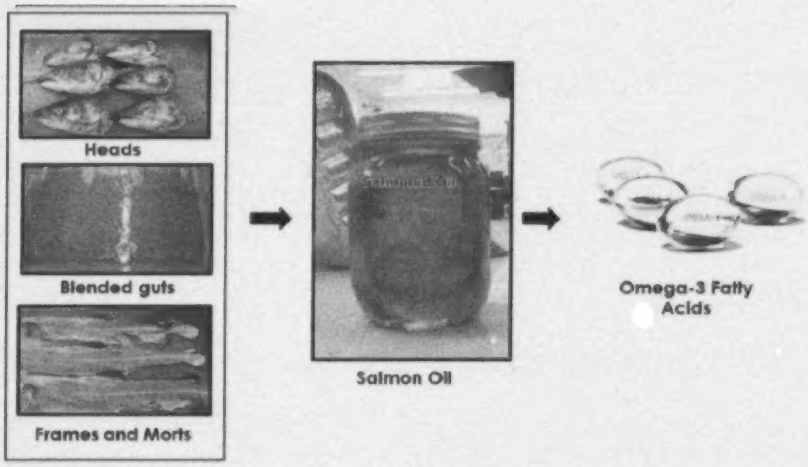
OMEGA-3 FATTY ACIDS FROM SALMON PROCESSING WASTE PRODUCED FROM NEWFOUNDLAND AQUACULTURE INDUSTRY



Omega-3 production from salmon processing waste

Newfoundland's aquaculture industry is dominated (95%) by salmonid production, worth $115 million/year. Processing of salmon generates large amounts of solid wastes, up to 45–50% of the body weight of the processed salmon. Currently, Newfoundland and Labrador has limited capacity to handle this waste in terms of composting, mink feed, rendering, and landfilling. The salmon waste has the potential to produce approximately 1600 tons of oil annually in Newfoundland and Labrador. Atlantic salmon and its processing by-products contains 2–15% lipid content and they are the one of the major sources of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). The omega-3 fatty acids possess various functional and biological properties including: prevention of atherosclerosis, arrhythmias, blood pressure, diabetes, manic-depressive illness, asthma, chronic obstructive pulmonary diseases, cystic fibrosis, cardiovascular disease, and improved learning ability. From our small scale study which we carried out at the CASD, Marine Institute, we determined that the omega-3 and omega-6 present in salmon by-products were 4–5 and 10–11 times higher, respectively, compared to salmon fillets. The higher EPA, docosapentaenoic acid (DPA) and DHA were present in the oil of the by-products which suggests that the oil can be utilized for various nutraceutical applications.

This work will result in increased awareness to the Newfoundland aquaculture producers and processors about the market potential of processing discards to generate high value-added products including omega-3 fatty acids.

MAR. 2013–MAR. 2014

FUNDED BY: Canadian Centre for Fisheries Innovation (CCFI) **CO-FUNDED BY:** Marine Institute of Memorial University of Newfounland

PROJECT LEAD: Deepika Dave

PROJECT TEAM: Vegneshwaran Ramakrishnan, Julia Pohling, Sheila Trenholm, Heather Manuel, Wade Murphy

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WAVE POWERED LAND-BASED INTERGRATED MULTI-TROPHIC AQUACULTURE

This research project being conducted by the College of the North Atlantic in Lord's Cove, Newfoundland, has the overall goal of developing a sustainable land-based integrated multi-trophic aquaculture system utilizing wave energy. This will lead to diversification of the economy in coastal communities.

There are many coastal towns and villages that are significant distances from ideal sea-based aquaculture sites. While shore-based aquaculture would be possible in many of these communities, the profitability of the industry is limited by the cost of pumping water to and through the shore-based infrastructure. Many existing coastal settlements do have an abundance of energy available in ocean waves. The harnessing of this energy to pump water on shore at low cost will enable the development of profitable shore-based aquaculture methods that will provide sustainable long-term economic activity for these communities. Shore-based aquaculture has the additional possibility of containing and directing effluent from the production of one species to another that can use it as a feed source (e.g., fish effluent delivered to filter feeders). This effectively "bio-filters" the fish production effluent while producing other marketable product (e.g., scallops and seaweed) at little or no extra cost.

SEP. 2011–SEP. 2016

FUNDED BY: Natural Sciences and Engineering Research Council (NSERC) **CO-FUNDED BY:** Research Development Corporation Newfoundland and Labrador

PROJECT LEAD: Leon Fiander (CNA)

PROJECT TEAM: Mike Graham

COLLABORATORS: Municipality of Lord's Cove, Newfoundland

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werc.servehttp.com/

Photo: Mike Graham, Margaret Mary Martin

USE OF THE OILSEED *CAMELINA SATIVA* AS A SOURCE OF LIPID AND PROTEIN IN DIETS FOR RAINBOW TROUT, ATLANTIC SALMON, AND ATLANTIC COD

The Camelina Project will provide information that can support the potential use of camelina in the Canadian aquaculture industry, which will provide opportunities for feed cost reduction through a nutritious, sustainable, made-in-Canada crop.

The Camelina Project was established in 2010, and four years of research has shown that camelina oil is a viable alternative to fish oil in diets for salmonids and cod. Consistently, camelina oil-containing diets produced fish with similar qualities compared to fish that were fed fish oil. Feeding trials replaced between 80–100% of fish oil with camelina oil in salmon smolts, salmon parr, Rainbow Trout, and cod. Growth performance was not affected in salmonids with 100% oil replacement; however, in cod the maximum replacement of fish oil with camelina oil was 80% before differences in growth performance were seen. In contrast, cod tolerated a 15% inclusion of camelina meal while salmon could only tolerate 8%; trout tolerance was in between. While fatty acid composition of the fillet is reflective of the diet, fish were capable of selectively retaining omega-3 fatty acids as well as synthesis of some eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) from precursors provided in the diets. Other key results include: positive health and immune responses; equivalent nutritional yields; and optimal marketable traits such as taste, colour, and texture. In comparison to other plant-based fish oil replacements, camelina oil's unique biochemical composition is highly compatible with fish health, performance, and product quality.

MAY 2010–MAR. 2015

FUNDED BY: Atlantic Canada Opportunities Agency **CO-FUNDED BY:** Genome Atlantic, Research and Development Corporation of Newfoundland and Labrador

PROJECT LEADS: Christopher Parrish, Matthew Rise (MUN); Derek Anderson (Dalhousie U)

Camelina sativa grown in an experimental plot in Truro, Nova Scotia. Photo: Stefanie Hixson

PROJECT TEAM: Stefanie Hixson, Xi Xue, Marije Booman, Tyler Brown, Tiago Hori (MUN); Chang Lin Ye, Stephanie Collins, Jing Lu, Jamie Fraser, Christina Bullerwell (Dalhousie U)

COLLABORATORS: Claude Caldwell (Dalhousie U); Isobel Parkin, Dwayne Hegedus (AAFC); Cara Kirkpatrick, David Spurrell, Kim Johnstone (Genome Atlantic)

CONTACT: cparrish@mun.ca

http://www.genomeatlantic.ca/projects/view/1-Camelina

RESILIENCE OF COASTAL ECOSYSTEMS TO GREEN CRAB INTRODUCTION AND REMOVAL

Non-native species threaten biodiversity and, in the oceans, can decrease the productivity of farmed and wild fisheries. While removal of non-natives is a common remediation approach, it does not guarantee that a site will return to its pre-disturbance state. If eradication or reduction of non-native species is not accompanied by mitigation strategies to increase population resiliency, a site may convert to an alternate stable state with decreased productivity.

In the northern Atlantic, oysters and eelgrasses provide essential habitat for many ecologically and commercially important fisheries (e.g., halibut, Soft-Shelled Clams, Rock Crab, salmon, oysters, and mussels). The non-native Green Crab (*Carcinus maenus*) may threaten these habitats by consuming molluscs, including reef-forming oysters, and by digging and degrading the quality of eelgrass beds. The resilience of these ecosystems to Green Crab disturbances is unknown.

Using field surveys along the existing gradient in Green Crab densities in PEI, we will test the hypotheses that: (1) Green Crabs are reducing the densities and health of eelgrass beds; (2) recovery of eelgrass density and health will be fastest when eelgrass and oysters are in close proximity; (3) eelgrass wasting disease (WD) is inhibiting the recovery of eelgrasses; and (4) WD prevalence is greater where oysters do not co-occur.

We propose to quantify the impacts of Green Crabs on coastal marine habitats and evaluate the effects of a new Green Crab fishery on the recovery of these systems.

MAY 2014–APR. 2015

FUNDED BY: Canada Excellence Research Chair (CERC) – Aquatic Epidemiology, UPEI

PROJECT LEAD: Sophie St. Hilaire (UPEI)

PROJECT TEAM: Maya Groner, Ruth Cox (UPEI)

CONTACT: ssthilaire@upei.ca

Maya Groner conducting Green Crab research. Photo: Maya Groner (UPEI)

Sophie St. Hilaire conducting Green Crab research. Photo: UPEI

CAPTURING SOCIAL VALUES IN OCEAN MANAGEMENT AND PLANNING: NEW TOOLS FOR NEW TIMES

Healthy marine social-ecological systems, including aquaculture and fisheries, are significant to the social and economic wellbeing of coastal communities. However, marine social-ecological systems are threatened by human-caused pressures. A common response to these pressures has been an increase in participatory management and planning processes, intended to accommodate and integrate input from all sectors. One of the key challenges to this happening is the current reliance on economic values as proxies for human socio-cultural values and/or the omission of key social and cultural considerations. While most agree that social values are important, gathering information on people's values regarding the ocean has proved to be challenging. We completed a pilot study using the "Q-method" to capture social values in the seafood sector in Campbell River, B.C. The Q-method combines qualitative and quantitative information and is increasingly used to explore subjective understandings of people in resource management contexts. This research aimed to capture and categorize people's social values/preferences relative to seafood and the ocean. The results illustrate the complexity and inter-relatedness of values, that values do no align neatly with sub-sector (e.g., harvesting, processing, fisheries, aquaculture, etc.), and the importance of context to social values related to seafood and the ocean.

Marine Harvest Canada's Cyrus Rocks farm. Photo: Patricia MacDonald (VIU)

We found that differences are not polarized into opposing "for" or "against" positions but are complex and nuanced. Our study also demonstrates that individuals' social values do not align within seafood sub-sectors (e.g., fishing, aquaculture, processing, retail, etc.) but rather cut across sets of preferences.

NOV. 2011–DEC. 2013

FUNDED BY: Social Sciences and Humanities Research Council (SSHRC)

PROJECT LEAD: Patricia MacDonald (VIU)

PROJECT TEAM: Grant Murray, Michele Patterson (VIU)

COLLABORATORS: Jim McIsaac (BC Commercial Fishing Caucus); Heather Coleman (Pacific Marine Analysis and Research Association)

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http://sites.viu.ca/icr/research/aquatic-foods-initiative/seafood-governance/

DEVELOPMENT OF DIET AND FEEDING REGIMES FOR COPPER ROCKFISH LARVAE

Copper Rockfish, *Sebastes caurinus,* are native to British Columbia and have excellent potential for aquaculture. There are, however, hatchery production problems that need to be resolved before commercial rockfish aquaculture can be undertaken. In this regard, there is a need to establish reliable protocols for the rearing of larvae from parturition to the juvenile stage. This project examined a variety of culture techniques for rearing larval Copper Rockfish, including different live feed enrichments (Cyclop-eeze, Ori-culture, Ori-green), lighting, and tank design.

Larvae that were fed live feed enriched with the Cyclop-eeze supplement (frozen copepods mixed with flake food) exhibited the best survival rate, with some larvae surviving to day 52. Larvae development (progression through larval stage) was fastest in larvae fed the live feed enriched with Ori-green, followed closely by those fed the Cyclop-eeze treatment.

This project was successful in the capture and initial rearing of Copper Rockfish larvae, and has greatly increased the understanding of the effect of different feeding regimes on the survival and development of these larvae. Research into alternate enrichments and combinations of treatments is ongoing. Future research will attempt to complete the lifecycle of this species, by transferring juveniles to a farm in order to demonstrate the full potential of this species to be cultured. The information gained through this research will be helpful in providing the basis for a sustainable commercial culture of this valuable and marketable fish.

APR. 2011–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP)

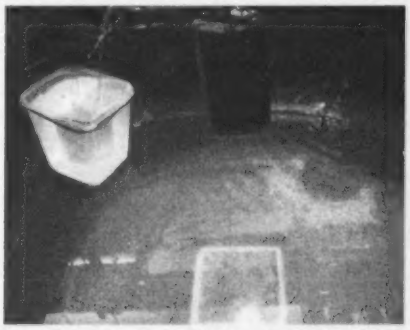
CO-FUNDED BY: Totem Marine Farms Inc.

PROJECT LEAD: Ian Forster (DFO)

COLLABORATORS: Totem Marine Farms Inc.

CONTACT: Ian.Forster@dfo-mpo.gc.ca

www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm



Detail of experimental culture vessel, showing drip feeder (left), blue light source (middle), and water inflow (right). The drain is visible in center bottom of the frame. Photo: Ian Forster (DFO)

Rockfish larvae in a culture tank. The tank drain is visible at the bottom of the image. Photo: Ian Forster (DFO)

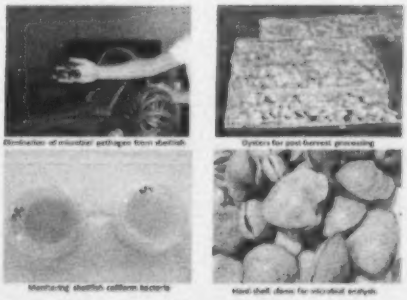
SHELLFISH MICROBIAL ELIMINATION THROUGH THE AQUALIFE FACILITY

Aqualife North America Inc. (ANA) a Canadian company, currently operating the Aquaport shellfish facilities in Avonport, Nova Scotia, is engaged in transporting live shellfish between North America and Western Europe through the Maersk Line. The company features patented Aqualife technology that utilizes specialized refrigerated containers for live shellfish purification, transporting, and trans-loading. To ensure that the live seafood for export to Europe are free of microbial contaminants and biotoxins that may affect the health and well-being of consumers, ANA had established a project collaboration with the research group of Jesse Ronquillo at the Faculty of Agriculture, Dalhousie University (formerly Nova Scotia Agricultural College). The objective was to put in place a system and test protocols to standardize the detection of shellfish microbial pathogens that are processed from the Aquaport facility, and to develop a method for eliminating microbial contaminants including the use of microalgae with bioactive compounds and rich in omega-3 fatty acids to improve shellfish nutritional quality and safety. The research results showed that the Aqualife technology eliminated potential microbial pathogens from bivalve molluscs that were destined for export. *Escherichia coli* or coliform bacteria were not detected from the shellfish samples processed at Aqualife facility.

The research project demonstrated that ANA Aquaport facility can be utilized as a shellfish depuration facility that can pass the rigid standards of Canadian Food Inspection Agency (CFIA) for export. It will assure European consumers of the safety and healthful quality of bivalve molluscs exported from the Maritimes using the Aqualife technology.

FEB. 2012–AUG. 2012

FUNDED BY: Nova Scotia Economic and Rural Development (NSERD) – Productivity and Innovation Program



Post-harvest processing and microbial analysis of shellfish at Aqualife facility. Photo: Jesse Ronquillo (UBC)

PROJECT LEAD: Jesse Ronquillo (UBC)

PROJECT TEAM: Audrie-Jo McConkey, Sadish Srinivassane (Dalhousie U)

COLLABORATORS: Bernhard Benkel, Katherine Rutherford (Dalhousie U); Gordon Neal (Aqualife North America, Inc.)

CONTACT: Jesse.Ronquillo@ubc.ca

CENTER FOR AQUACULTURE TECHNOLOGIES CANADA AQUACULTURE RESEARCH FACILITY

Currently there are no dedicated, privately held aquaculture research facilities operating to a high level of regulatory compliance in Canada. The completed construction of the Center for Aquaculture Technologies Canada (CATC) aquaculture research facility will enable new fish health and nutrition products to come to market sooner and will provide high quality R&D support for the aquaculture industry.

CATC is a contract research organization supporting the application of technology to enhance the productivity and sustainability of aquaculture. CATC has decided to expand their operations and are currently planning a 20,000 square foot facility to be constructed in Kings County, Prince Edward Island. The new facility is designed to enable *in vitro* and *in vivo* testing. Approximately half of the wet lab space is dedicated to projects requiring pathogen containment (AQC3). Wet lab area outside the containment zone is committed to maintaining research lines and for studies not requiring pathogen containment, such as the evaluation of: animal performance, diets, and novel feed ingredients. Individual wet labs in all areas will contain dedicated air handling and water recirculation systems, which provide inward directional air flow and fresh or saline ground water at temperatures ranging from 8–16 °C. A well-equipped molecular laboratory supports the development and application of genetic tools including PCR-based diagnostics, SNP genotyping, and genomics applications. The facility has been designed to meet the regulatory requirements of Canadian Food Inspection Agencies Office of Biohazard and Containment Safety and Public Health Agency of Canada. Construction and commissioning are expected to be complete by the end of Q2 2015.

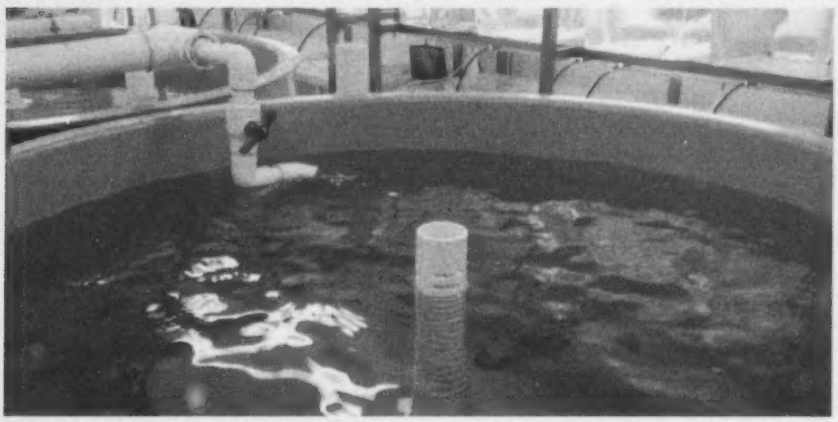


Photo: Center for Aquaculture Technologies (CATC)

SEP. 2014–JUN. 2015

FUNDED BY: Prince Edward Island
CO-FUNDING BY: ACOA; Center for Aquaculture Technologies Canada (CATC); Regis Duffy Bioscience Fund

PROJECT LEAD: Debbie Plouffe (CATC)

PROJECT TEAM: Matt Bryenton (CATC); John Buchanan (Center for Aquaculture Technologies)

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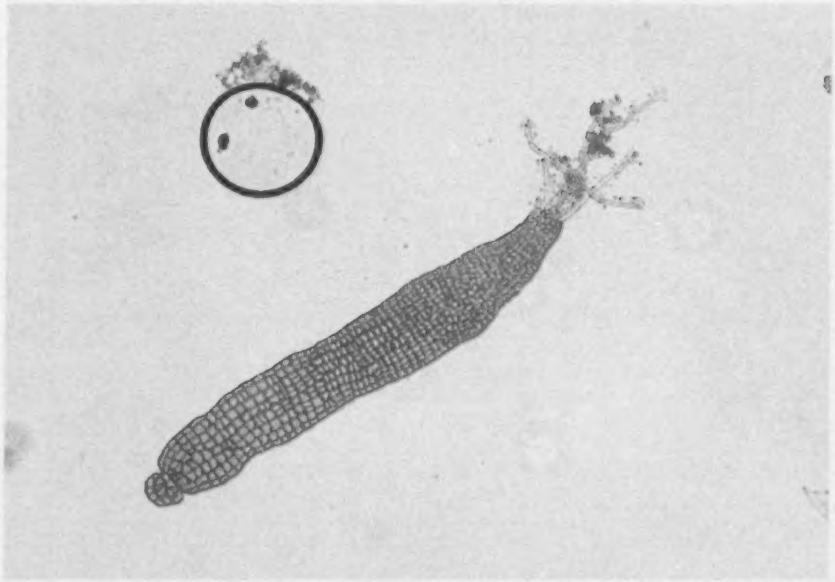
OPTIMAL PROGRAM: LAYING THE GROUNDWORK FOR AN INTEGRATED APPROACH TO DEVELOPING THE CULTURED ALGAE INDUSTRY IN QUEBEC

This program will have a structuring effect, helping to establish ties between sectors that, to date, have been separate (aquaculture and nutraceuticals). In addition to supporting efforts to diversify the mariculture industry in Quebec, the program innovations will generate benefits for communities in three regions (Gaspé Peninsula/Îles-de-la-Madeleine, North Shore, Chaudière-Appalaches) as well as potential spin-off benefits in Mauricie and Montérégie. Development of this integrated approach will also help to foster an environment conducive to the emergence of new businesses in both the marine and the biotechnology sectors.

Many Canadian companies are involved in the development and exploitation of marine macroalgae, a highly innovative field that has generated interest in its industrial potential across a broad range of sectors, including cosmetics, bio-food, medicine, textiles, and energy. In Eastern Canada, options for harvesting from seagrass beds are significantly restricted, whereas algae aquaculture offers numerous advantages. Kelp, a family of brown algae, has been subjected to extensive and conclusive culture testing in Quebec. Marine aquaculture enterprises (mussels, scallops) are currently ready to incorporate algae into their production schedules, while one marine hatchery has already taken its first steps in algae culture. It is against this backdrop of mariculture diversification that Merinov, the Centre collégial de transfert de la technologie (CCTT) of Cégep de la Gaspésie et des Îles, and Oléotek, the CCTT of Cégep de Thetford, propose to establish a joint work program targeting development of an integrated approach to developing the cultured algae industry. The OPTIMAL program has three focuses: (1) improving algae culture productivity; (2) developing high value-added products (foods and active ingredients); and (3) recovering residue from algae processing in the form of byproducts (energy, packaging, food, textiles) from a zero-waste perspective.



Young plantlet of hatchery-cultivated Sweet Kelp (*Saccharina latissima*), 900 micrometers in length (optical microscope photo)

Monitoring growth of Sweet Kelp (*Saccharina latissima*) cultivated in a submerged system at a marine farm in the Gaspé Peninsula

JUN. 2014–MAY 2019

FUNDED BY: Natural Sciences and Engineering Research Council – College and Community Innovation (NSERC – CCI) Program
CO-FUNDED BY: FRQNT – Programme Regroupements stratégiques, Ressources Aquatiques Québec (RAQ)

PROJECT LEAD: Michel Lamvée (CÉGEP de la Gaspésie et des Îles)

PROJECT TEAM: Aurélie Licois, Grégory Hersant, Eric Tamigneaux, Karine Berger

COLLABORATORS: Roxane Bernier, Jean-Claude Blais, Daniel Bourdages, David Fortin, Isabelle Gendron-Lemieux, Marie Lionard, Henryette Michaud, Lisandre Solomon, Marie-Pierre Turcotte

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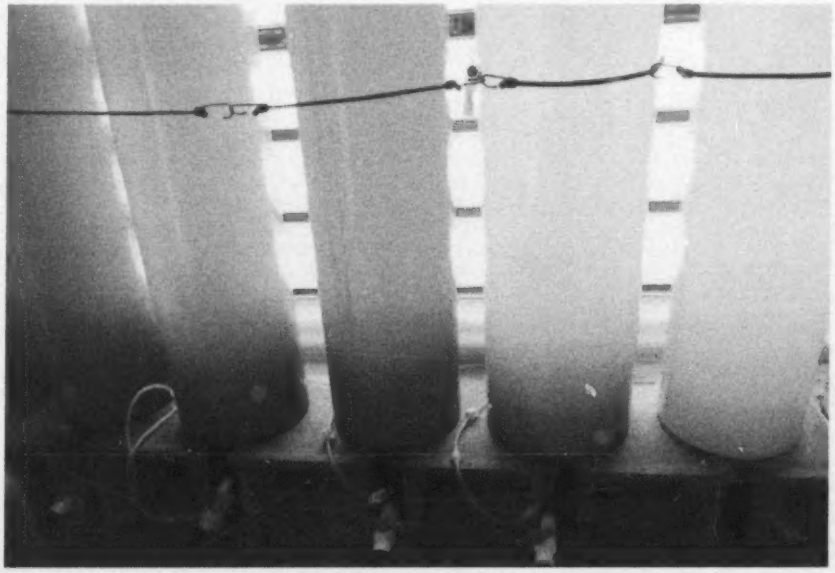
UTILIZING ALTERNATE WAVELENGTHS TO INCREASE LEVELS OF THE OMEGA-6 ARACHIDONIC ACID (ArA) IN MICROALGAE

The result of this study will help improve the efficient production of arachidonic acid (ArA) using microalgae for human health and for use in aquaculture feeds.

Selected microalgal species from the classes Prasinophyceae (*Isochrysis galbana, Pavlova lutherii, Pseudoisochrysis paradoxa*), Coscinodiscophyceae (*Tetraselmis striata, T. succia, T. chuii*) and Prymnesiophyceae (*Skeletonema dohrnii, Thalassiosira pseudonana*) were grown in triplicate under different light wavelength environments of red (680 nm), blue (425 nm), green (550 nm), and a standard fluorescent light to determine if growth and the lipid content of arachidonic acid (ArA) (20:4n-6) would be altered. The role of ArA is linked to several health benefits with a particular association to the human nervous system. Supplementary diets have been produced including ArA for products such as baby formula and aquaculture feeds. Growth for all tested classes was found to be greatest under the influence of red wavelengths (p=0.001), followed by blue, then green and the standard, respectively. Wavelength was validated using a spectrophotometer (HACH DR2700). After a growth curve was established, the cultures were inoculated so that samples could be drawn and analyzed during the exponential phase under each wavelength. The levels of ArA were determined through gas chromatography. Algae grown at both the red and blue wavelengths exhibit greater cell density as well as an increase in levels of ArA compared to the standard or green wavelength.



Microalgal culture using standard fluorescent light. Photo: Jesse Ronquillo (UBC)

MAR. 2007–NOV. 2013

FUNDED BY: Atlantic Canada Opportunities Agency – Atlantic Innovation Fund (ACOA-AIF)

PROJECT LEAD: Audrie-Jo McConkey (Dalhousie U)

PROJECT TEAM: Jesse Ronquillo (UBC)

CONTACT: amcconkey@dal.ca

IDENTIFYING CRITICAL ECOLOGICAL THRESHOLDS FOR TUNICATE INFESTATIONS ON MUSSEL FARMS

Bio-fouling is a well-documented shellfish aquaculture industry challenge and the recent introduction of several invasive tunicate species has greatly inflated its impact. The PEI mussel aquaculture industry has been particularly affected by the introduction of four new tunicate species: Clubbed Tunicate (*Styela clava*) in 1998 in the eastern end of the province; Golden Star Tunicate (*Botryllus schlosseri*) in 2001 and 2002 and Violet Tunicate (*Botrylloides violaceus*) were both reported on the north coast of PEI; and in 2004, the Vase Tunicate (*Ciona intestinalis*) was first reported on the east coast of the island. Efforts to control the spread of these tunicate species have been relatively successful, but presently most mussel producing areas in PEI are infested with at least one tunicate species. Currently, high pressure water spray is the main technique used by the mussel industry to control tunicate fouling. Lime dipping is also used to control tunicates, particularly the Clubbed Tunicate, on mussel socks. Efforts to develop the most cost-effective treatment strategy are continuing while specific ecological thresholds are not yet established. The establishment of both economical and ecological thresholds are key to the sustainability of the mussel industry in PEI and could lead to the creation of the first Integrated Pest Management approach for Aquatic Invasive Species. The goal of this project is to investigate the ecological impact of tunicate treatment with the following objectives: (1) develop a method to estimate the tunicate biomass on mussel farm structures; (2) develop a model to predict the impact of tunicates fall-off, pre- and post-treatment, on the benthic environment; and (3) assess the impact of tunicate filtration and biodeposition on ecosystem productivity. Results from this project will also provide information on timing and coordination of treatment.

APR. 2011–MAR. 2014

FUNDED BY: DFO – Program for Aquaculture Regulatory Research (DFO – PARR)

PROJECT LEAD: Thomas Landry (DFO)

PROJECT TEAM: Jeff Davidson, Thitiwan Patanastienkul (AVC-UPEI); Luc Comeau, Andrea Locke, Thomas Guyondet, Daniel Bourque, Monique Niles, Chris McKindsey (DFO); Aaron Ramsay (PEI Department of Fisheries, Aquaculture and Rural Development)

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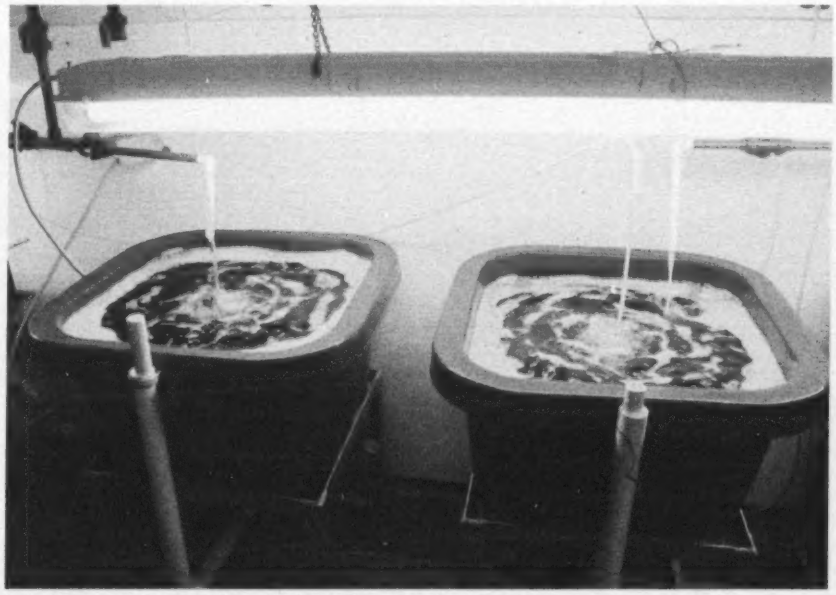
ASSESSING THE EFFICIENCY OF A MACROALGAE BIOFILTER IN REGULATING NITRATE AND PHOSPHATE CONCENTRATIONS IN TANKS AT THE MONTRÉAL BIODÔME, IMITATING THE ECOSYSTEM OF THE GULF OF ST. LAWRENCE

Palmaria palmata. Photo: École des pêches et de l'aquaculture du Québec (ÉPAQ)



Palmaria palmata culture tanks. Photo: Anne Tremblay-Gratton (U Laval)

The development and scale-up of a working algae biofilter prototype would provide marine farms using intensive recirculation with a biological treatment system to complement existing bacteria filters. An algae biofilter would also be a useful tool for water treatment at public aquariums.

In intensive circulation systems, high concentrations of dissolved nitrogen or phosphorus can become significant stressors for aquatic organisms. A sulphur denitrator is currently being used in the live collections tanks at the Montréal Biodôme to control nitrate levels. However, this system has a number of disadvantages (oxygen consumption, production of hydrogen ions and sulphate), which has led us to seek an alternative solution for controlling phosphorus build-up. Certain phylloid marine macroalgae, which benefit from a high surface area-to-volume ratio, have the capacity to quickly absorb nitrogen nutrients as well as phosphate and carbon dioxide to produce oxygen. In addition, some species with high growth rates are easy to cultivate in tanks.

The objective of the project is to develop a macroalgae biofilter that is efficient at nitrate and phosphate removal under experimental conditions similar to those created in the marine ecosystem at the Montréal Biodôme. To this end, the denitrification and dephosphorylation of two indigenous species, *Ulva lactuca* and *Palmaria palmata*, are evaluated under the same operating conditions (9 g/L, 28 PSU, 9°C and 13°C, $N\text{-}NO_3$: $P\text{-}PO_4$ of 40:4, 50:6, 60:8 mg/L) at the ÉPAQ facilities in Grande-Rivière.

JAN. 2014–APR. 2016

FUNDED BY: Société des Amis du Biodôme de Montréal (SABM); MITACS Accélération; Fonds de recherche du Québec – Nature et technologies (FRQNT); Fonds d'amorçage et de partenariat UQAR-Merinov (FAP) **CO-FUNDED BY:** Natural Sciences and Engineering Research Council (NSERC) Industrial Research Chair for Colleges in the Conversion of Marine Macroalgae; Montréal Biodôme; OrganicOcéan Inc.; Ressources Aquatiques Québec (RAQ)

PROJECT LEAD: Nathalie Le François (U Laval)

PROJECT TEAM: Anne Tremblay-Gratton (U Laval)

COLLABORATORS: Éric Tamigneaux (ÉPAQ); Jean-Christophe Boussin (Montréal Biodôme); Grant Vandenberg (U Laval)

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ANAEROBIC DIGESTION OF FISH OFFAL AND SAWDUST

Anaerobic digestion is an attractive option for manure/waste management because of its potential to digest agricultural and industrial residues, while reducing greenhouse gas (GHG) emissions, mitigating pathogens and odours, and increasing ionized nutrients in the material being digested. This study will test this option by investigating the digestion of fish offal and sawdust using 20-L digesters (microorganisms that break down biodegradable material) under two operational strategies. The digester studies will focus on optimizing biogas/methane production by changing organic loading rates, ratio of fish offal to sawdust, and feeding technique (batch vs. semi-continuous). The biogas/methane yields determined in this study will be used to assess the economic and performance feasibility of a full scale system.

APR. 2011–MAR. 2013

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Meeker's Aquaculture

PROJECT LEAD: Doug Geiling (DFO)

PROJECT TEAM: Richard Moccia, David Bevan, Anna Crolla, Chris Kinsley (U Guelph)

COLLABORATORS: Meeker's Aquaculture

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

ESTABLISHING AN ECOTOXICOLOGY WET LAB TO COLLECT NON-TARGET THERAPEUTANT DATA FOR PHARMACEUTICAL COMPANIES AND REGULATORS

The Huntsman Marine Science Centre along with New Brunswick Department of Agriculture, Aquaculture and Fisheries (NBDAAF) recognized the need to develop a suitable research wet lab that has appropriate capacity to complete long-term ecotoxicology studies, particularly focused on American Lobster. These studies are required for new therapeutant approvals prior to use on fish farm sites in Atlantic Canada. This project upgraded an existing Huntsman building on its lower campus that has an isolated location and appropriate footprint to complete long-term seasonal studies involving representative populations of adult American Lobsters. Specific facility upgrades included preparation of all surfaces to receive multiple coats of an appropriate epoxy coating and new steel doors for entry to the wet lab space to provide additional security and weather proofing to the space. Adult American Lobster holding tanks were also purchased to facilitate the start of new projects. All of these upgrades add tremendous value to the Huntsman facilities and our service provision in environmental toxicology research to a global client base. As a result of this effort, several international pharmaceutical companies have engaged the Huntsman with plans to initiate non-target American Lobster research projects in the near term.

Required regulatory data collection includes the effects of novel sea lice treatment compounds on non-target American Lobsters before new therapeutants are approved for use in Canada. These facility upgrades allows the Huntsman to conduct such experiments in local environmental conditions.

JAN. 2014–MAR. 2014

FUNDED BY: NB Department of Agriculture, Aquaculture and Fisheries **CO-FUNDED BY:** Huntsman Marine Science Centre (HMSC)

PROJECT LEAD: Chris Bridger

PROJECT TEAM: Les Burridge (HMSC); Mike Beattie (NBDAAF)

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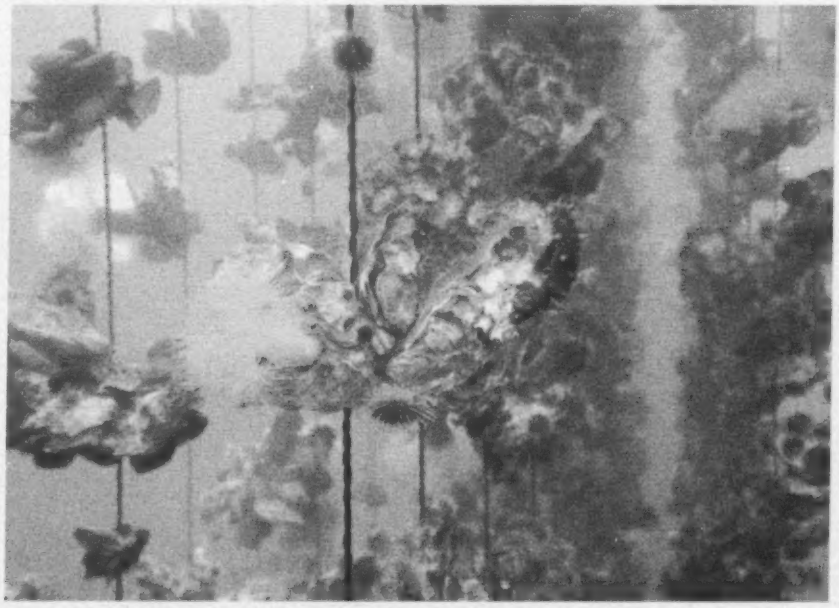
www.huntsmanmarine.ca

BENTHIC CULTURE OF SEA CUCUMBERS: ASSESSING INTERACTIONS BETWEEN CULTURED AND WILD POPULATIONS AND THE MITIGATION OF ENVIRONMENTAL IMPACTS IN SHELLFISH CO-CULTURE



Juvenile California Sea Cucumber, *Parastichopus californicus*, perched on an oyster dump amid a forest of oyster culture strings. Photo: Dan Curtis (DFO)

Expanding our knowledge of benthic ranching techniques for the California Sea Cucumber, *Parastichopus californicus*, and addressing issues such as containment of this species will be mutually beneficial to resource managers and industry partners.

High market demand has resulted in a great deal of interest in culturing *P. californicus* in British Columbia (BC). However, before these operations can proceed to full scale production, additional base-line data are needed to determine the viability and potential impacts of culturing sea cucumbers. The primary aims of this project are to determine: (1) the growth and survival of sea cucumbers in benthic culture; (2) the environmental impact of sea cucumber aquaculture; and (3) the potential interactions between wild and benthic-ranched individuals. Early results from this project are promising for sea cucumber aquaculture in BC. Juvenile individuals have shown good growth and survival when raised in benthic cages both on and away from an existing deep-water oyster farm. When co-cultured with oysters, the nutrient rich benthic habitat at these sites may allow for higher growth rates and stocking densities. High densities of sea cucumbers often found at existing aquaculture sites may help to ameliorate some of the nutrient loading and associated environmental impacts of shellfish aquaculture. However, seasonal changes in sea cucumber density at our study site suggest that if preventing mixing of wild and cultured stocks is desired, some form of containment may be necessary.

APR. 2012–MAR. 2015

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Fan Seafoods Ltd.; Klahoose First Nation; Pacific Sea Cucumbers Harvesters Association; Viking Bay Ventures

PROJECT LEAD: Chris Pearce (DFO)

PROJECT TEAM: Dan Curtis, Nick Duprey, Claudia Hand (DFO); Scott McKinley (UBC)

COLLABORATORS: Fan Seafoods Ltd.; Klahoose First Nation; Pacific Sea Cucumbers Harvesters Association; Viking Bay Ventures

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www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm

ISOLATION, CULTURE, AND GENOMIC ANALYSIS OF HARMFUL ALGAL SPECIES AFFECTING AQUACULTURE ON THE WEST COAST OF CANADA AND ANALYSIS OF THE HARMFUL ALGAE MONITORING PROGRAM HISTORICAL DATABASE

Harmful Algal Blooms (HABs) are responsible for considerable economic losses due to cultured finfish/shellfish mortalities and toxic harmful algae in shellfish can threaten human health. With the support of the British Columbia salmon aquaculture industry, the Harmful Algae Monitoring Program (HAMP) was established in 1999 as a community program to address the devastating effect of harmful algae on farmed fish. Researchers needed to identify certain HAB species, cultivate these species for study, and analyze previous HAMP data to investigate potential trends between HABs and environmental parameters.

Five harmful algal species (with 17 strains in total) were isolated and identified through microscope observation and genetic analysis. These species are in culture at the Pacific Biological Station (PBS), as well as archived with the Canadian Centre for the Culture of Microorganisms at the University of British Columbia, allowing for potential future studies on algal genetics, toxin production, and non-microscopic methods of harmful algae detection. Harmful algal identification posters were created to assist industry in identifying various HAB species. In addition, the analysis of the data collected by the HAMP over the last thirteen years has shown some correlations between various environmental variables and blooms of particular harmful algae species. The results of this research will aid the aquaculture industry in early prediction of HABs and their potential effects, allowing for the early adoption of suitable mitigation measures.

APR. 2012 – MAR. 2014

FUNDED BY: DFO – Aquaculture Collaborative Research and Development Program (DFO – ACRDP) **CO-FUNDED BY:** Cleanwater Shellfish Ltd.; Creative Salmon Company Ltd.; Grieg Seafood BC Ltd.; Island Scallops Ltd.; Little Wing Oysters Ltd.; Mac's Oysters Ltd.; Mainstream Canada; Marine Harvest Canada Inc.; Nelson Island Sea Farms Ltd.; Taylor Shellfish Canada ULC.

PROJECT LEAD: Chris Pearce (DFO)

PROJECT TEAM: Kristi Miller, Amy Tabata, Laurie Keddy (DFO); Nicky Haigh, Svetlana Esenkulova (Microthalassia Consultants Inc.)

COLLABORATORS: Cleanwater Shellfish Ltd.; Creative Salmon Company Ltd.; Grieg Seafood BC Ltd.; Island Scallops Ltd.; Little Wing Oysters Ltd.; Mac's Oysters Ltd.; Mainstream Canada; Marine Harvest Canada Inc.; Nelson Island Sea Farms Ltd.; Taylor Shellfish Canada ULC.

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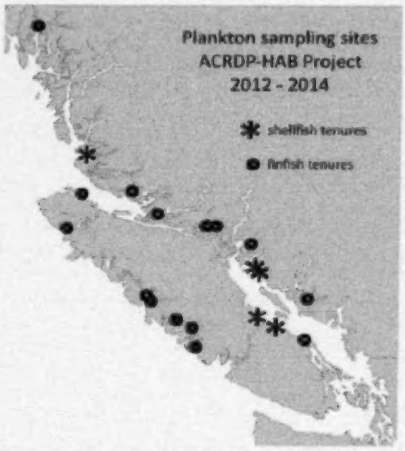
www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm



Plankton sampling sites for Harmful Algal Blooms from 2012–2014

Bloom of *Heterosigma akashiwo* in Kyuquot Sound, British Columbia. Photo: Nicky Haigh (Microthalassia Consultants Inc.)

INNOVATIVE APPROACHES TO WATER TREATMENT FOR LAND BASED FISH FARMS FOR RECIRCULTION AND DISCHARGE

Land based fish farms are a rapidly growing aquaculture industry which brings tremendous benefits to Ontario. Concurrent with the growth of this industry is also an increase in the generation of waste-waters that have the potential to negatively affect natural receiving waters. The work undertaken within this project investigates treatment technologies that are common in high strength municipal and industrial settings to assess their efficacy for use with low strength aquaculture waste-waters. Project partners are investigating the use of ultra-filtration to determine its impact upon microbial populations within a recirculating aquaculture system (RAS) regime and whether change in carbon to nitrogen ratios will enhance or inhibit the development of autotrophic nitrifiers and thus influence the efficiency of the RAS. We are also investigating the use of an innovative fixed film membrane to determine how well it performs in the oxidation of carbon compounds and the transformation of nitrogenous wastes. Work is progressing on assessing the management options available for the use of phosphorus adsorptive media and the generation of a standardized dose for the ultraviolet inactivation of *Flavobacterium psychrophilum* and *Saprolegnia parasitica* using a collimated beam protocol.

It is believed this work will provide aquaculture managers additional options for the treatment of wastewaters and or the improvement of water quality within recirculating aquaculture systems.

Sampling of waste-water ponds to determine phosphorus budget. Photo: Nick Jewett (Queen's U)

JUN. 2012–JUN. 2015

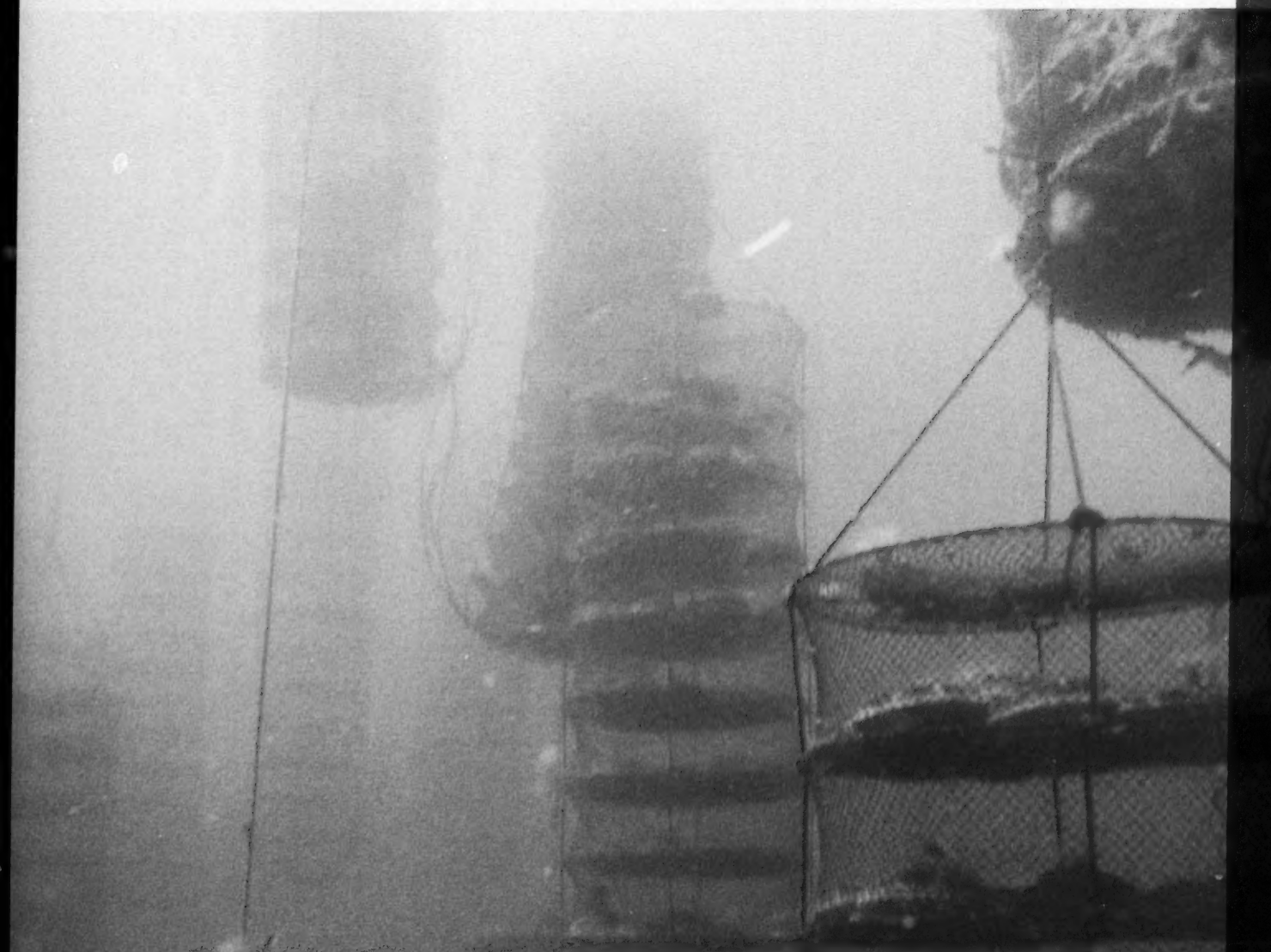
FUNDED BY: Ontario Ministry of Agriculture, Food and Rural Affairs **CO-FUNDED BY:** NSERC

PROJECT LEAD: Brent Wootton (Fleming College)

PROJECT TEAM: Bruce Anderson (Queen's U); Robin Slawson (Wilfrid Laurier U); Christopher Murray (Lakehead U); Rob Davis (Ecoethics); Stewart Hayes (Trojan UV); John Gillis (Measuremax); Karen Tracey (NOAA); Joe Garbin (Contech)

CONTACT: Brent.Wootton@flemingcollege.ca

An integrated multi-trophic aquaculture (IMTA) site. Photo: DFO



ORGANIZATIONS

- FISHERIES AND OCEANS CANADA (DFO)
  - PROGRAM FOR AQUACULTURE REGULATORY RESEARCH (PARR)
  - AQUACULTURE COLLABORATIVE RESEARCH AND DEVELOPMENT PROGRAM (ACRDP)
  - CENTRE FOR AQUATIC ANIMAL HEALTH RESEARCH AND DIAGNOSTICS (CAAHRD)
  - GENOMICS RESEARCH AND DEVELOPMENT INITIATIVE (GRDI)
- NATIONAL RESEARCH COUNCIL (NRC) INDUSTRIAL RESEARCH ASSISTANCE PROGRAM (IRAP)
- THE NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL OF CANADA (NSERC)
  - NSERC ENGAGE GRANTS
- CANADA EXCELLENCE RESEARCH CHAIRS (CERC)
- SOCIAL SCIENCES AND HUMANITIES RESEARCH COUNCIL (SSHRC)
- RESSOURCES AQUATIQUES QUEBEC (RAQ)
- ATLANTIC CANADA OPPORTUNITIES AGENCY (ACOA)
- MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (MINISTÈRE DE L'AGRICULTURE, DES PÊCHERIES ET DE L'ALIMENTATION DU QUEBÉC - MAPAQ)
- MERINOV
- GENOME CANADA
- GENOME ATLANTIC

FISHERIES AND OCEANS CANADA (DFO)

Fisheries and Oceans Canada **Pêches et Océans Canada**

DFO delivers programs and services that support the sustainable use and development of Canada's waterways and aquatic resources. On behalf of the Government of Canada, DFO is responsible for developing and implementing policies and programs in support of Canada's scientific, ecological, social, and economic interests in oceans and fresh waters. It is DFO's mission to deliver to Canadians the following outcomes:

- Economically Prosperous Maritime Sectors and Fisheries;
- Sustainable Aquatic Ecosystems; and
- Safe and Secure Waters.

In working toward these outcomes, the Department is guided by the principles of sound scientific knowledge and effective management.

DFO is the lead federal department for the sustainable management of fisheries and aquaculture. Responsibility for aquaculture management and development (governance) is shared between the federal, provincial and territorial governments. We work together, with many other partners, to ensure that the legislative and regulatory framework for aquaculture is responsive to the public's and industry's needs.

Photo of the CCGS *Viola M. Davidson* anchored at St. Andrews Biological Station (SABS, DFO). This is a specialty vessel, being a small, shallow draught vessel, used primarily for science research. Photo: Roger Wysocki (DFO)

DFO's aquaculture research aims to address regulatory knowledge gaps, and collaborative research and development with the aquaculture industry. Collaborative research facilitates the transfer of the latest technologies to the aquaculture industry. Research on the environmental effects of aquaculture also provides a solid scientific foundation for the conservation and protection of fish and fish habitat in marine or freshwater ecosystems. On-going research contributes to scientific certainty with respect to aquaculture operations and how they interact with the aquatic environment.

In recent years, DFO's research effort has been directed at understanding environmental effects of aquaculture on freshwater and marine habitat and ecosystems. We also invest in aquatic animal health research to understand how best to prevent, mitigate and treat disease. As species diversification is often seen as a means of increasing Canada's global market share, DFO scientists also play a key role in innovative research.

Further information on priorities, plans, programs and projects can be found on the DFO web site: **http://www.dfo-mpo.gc.ca.**

The following DFO programs are currently supporting Canadian aquaculture research:

Program For Aquaculture Regulatory Research (PARR)

The Program for Aquaculture Regulatory Research (PARR) is an internal DFO research program that supports targeted research projects focused on increasing the relevant science knowledge base to support and advise informed DFO ecosystem-based environmental regulation and decision making for the aquaculture sector.

Originally funded in 2008 as part of the Sustainable Aquaculture Program, and recently renewed through to 2018, PARR supports research that addresses both national and regional regulatory priorities, focusing on increasing the scientific knowledge base in the following areas: environmental effects from and identifying approaches to optimize the management of fish pathogens and fish parasites; cultured-wild fish interactions; effects associated with the release of organic matter from aquaculture activities; understanding habitat interactions; and cumulative effects and ecosystem management.

Since 2010, PARR has approved and funded over 40 targeted projects.

For more information, please visit **http://www.dfo-mpo.gc.ca/science/environmental-environnement/aquaculture/parr-prra/index-eng.asp**

Aquaculture Collaborative Research and Development Program (ACRDP)

The Aquaculture Collaborative Research and Development Program (ACRDP) is a DFO initiative to increase the level of collaborative research and development activity between the aquaculture industry and the department, and in some instances with other funding partners. The ACRDP teams industry with DFO researchers to undertake research activities that lie within the mandate of DFO but are based on the needs and priorities of the aquaculture industry. The program allocates ACRDP funds to collaborative research projects that are proposed and jointly funded by aquaculture producer partners. The ACRDP funding is approximately $2 million per year and projects are funded through a nationally competitive process.

The key goals of the program are to improve the competitiveness and sustainability of the Canadian aquaculture industry; increase collaborative research between the department and industry; facilitate the process of technology transfer and knowledge mobilization; and increase scientific capacity of the Canadian aquaculture industry for essential aquaculture research and development.

The broad research and development objectives, under which National and Regional priorities are established, are twofold:

- Optimal fish health; and
- Environmental performance.

Since the program's inception in 2001, approximately 440 projects have been approved and funded. Over the last five years, DFO and collaborators have invested approximately $10 M into research collaborations for the ACRDP.

For more information, please visit: **www.dfo-mpo.gc.ca/science/enviro/aquaculture/acrdp-pcrda/index-eng.htm**

Centre For Aquatic Animal Health Research And Diagnostics (CAAHRD)

The Centre for Aquatic Animal Health Research and Diagnostics (CAAHRD) coordinates targeted research, the development of quality diagnostics and the provision of sound scientific advice in support of the NAAHP as well as regional aquatic animal health programs overseen by DFO. The goal is to keep exotic diseases out and to ensure that diseases confined to particular areas don't spread through the movement of fish or fish products. In addition, Canada has to satisfy trading partners that its exports of fish and fish products do not carry any infectious diseases, and that rule of trade requires a lot of testing.

CAAHRD research is conducted by scientists in DFO's National Aquatic Animal Health Laboratory System (NAAHLS). Disease research on live animals for the NAAHP program is done in Canada's only federal laboratory certified as Aquatic Containment Level 3 (DFO's Gulf Biosecurity Unit – Aquatic Animal Health Lab in Charlottetown PEI). Diagnostic test development and other research on the pathogens are done by DFO NAAHLS scientists there and at three other NAAHLS facilities: the Gulf Fisheries Centre Aquatic Animal Health Lab (Moncton, New Brunswick), The Freshwater Institute Aquatic Animal Health Lab (Winnipeg, Manitoba) and, the Pacific Biological Station Aquatic Animal Health Lab (Nanaimo, British Columbia).

For more information, visit **http://www.dfo-mpo.gc.ca/science/publications/article/2011/02-28-11-eng.html**

Genomics Research and Development Initiative (GRDI)

Fisheries and Oceans Canada (DFO) uses genomics for the aquaculture industry and in the management of the wild fishery. These tools lead to better disease identification and control, development of techniques to accurately determine the population structure of wild marine fish, and to identify endangered species and minimize illegal or inadvertent harvesting. As an enabling technology, genomics provides powerful tools and precise information to support operational mandates and upon which policy and regulatory decisions can be based.

The GRDI was established for the purpose of building and maintaining capacity inside government departments to do genomics research. Through targeted investments the Initiative has enabled the establishment of critical mass in genomics research that supports innovation in key Canadian sectors, and ensures that federal departments can mobilize their support for the overall, national genomics effort (e.g., projects funded by Genome Canada, CIHR). Programs funded under the GRDI are also used to augment human resources and help create partnerships with other government departments, universities, and industry (where applicable) through the sharing of technology platforms and by collaborating in research areas that cut across traditional departmental sectors.

For information visit **http://www.dfo-mpo.gc.ca/Science/biotech/abgrds-srdbfa/index-eng.htm**

Aquatic animal health laboratory research involving Blue mussels (*Mytilus Edulis*) at Fisheries and Oceans Canada's Gulf Fisheries Centre. Photo: Nancy House (DFO)

NATIONAL RESEARCH COUNCIL (NRC) INDUSTRIAL RESEARCH ASSISTANCE PROGRAM (IRAP)

Enabling small- and medium-sized aquaculture businesses succeed through innovation

Delivered by a comprehensive network of Industrial Technology Advisors (ITAs) and employees across Canada, the National Research Council Canada Industrial Research Assistance Program (NRC-IRAP) supports the needs of small- and medium-sized enterprises (SMEs) engaged in innovative or technology-driven activities.

NRC-IRAP provides a suite of business and technical advisory services, networking and linkages, and non-repayable financial assistance to SMEs. These services are adapted to the SMEs' industrial, socio-economic, and geographic make-up in order to provide a customized response to their development needs.

Since April 1, 2013, NRC-IRAP has provided over $3 M in financial support to aquaculture SMEs across Canada to assist them in their new product and process development, improvement, and adoption initiatives. Here are some examples of NRC-IRAP's financial support and innovative services to the aquaculture sector:

- NRC-IRAP supported Blacks Harbour, NB, company Kelly Cove Salmon Ltd. as part of a $3.8 million collaboration with the University of Guelph to develop genomics tools known as Simple Nucleotide Polymorphism (SNP) chips, along with traditional breeding practices to allow the company to select for salmon that have better flesh quality and are naturally more resistant to parasites and disease. The anticipated outcome is that genomics will help Kelly Cove Salmon Ltd. more accurately identify fish that are naturally more robust, meaning healthier fish that require less medication; and
- NRC-IRAP continues its support and work with the Atlantic Canada Aquaculture Research and Development Network (ACAIRDN). This helps continue the good work of R&D Coordinators (RDCs) in each of the Atlantic Canada Fish Farmers Association, the Aquaculture Association of Nova Scotia, the Newfoundland Aquaculture Industry Association, and the PEI Aquaculture Industry Alliance. NRC-IRAP has also supported RDCs and other initiatives in associations in BC, Ontario, Quebec, and in the NB shellfish industry. The presence of ACAIRDN and individual RDCs has increased the technical acumen of sector associations, enabling tech transfer to their members, establishing and communicating sector R&D priorities to stakeholders, increasing R&D coordination within the sector, and access to outside expertise for their members.

Canada NRC-CNRC

For more information on the program and to contact your local NRC-IRAP Industrial Technology Advisor, visit: **www.nrc.gc.ca/irap.**

THE NATURAL SCIENCES AND ENGINEERING RESEARCH COUNCIL OF CANADA (NSERC)

NSERC aims to make Canada a country of discoverers and innovators for the benefit of all Canadians. The agency supports university students in their advanced studies, promotes and supports discovery research, and fosters innovation by encouraging Canadian companies to participate and invest in postsecondary research projects. NSERC researchers are on the vanguard of science, building on Canada's long tradition of scientific excellence.

The agency supports almost 30,000 postsecondary students and postdoctoral fellows in their advanced studies. NSERC promotes discovery by funding approximately 12,000 professors every year and works with over 3,000 Canadian companies that are participating and investing in postsecondary research projects.

www.nserc-crsng.gc.ca

NSERC Engage Grants

An Engage Grant (EG) is intended to give a company that operates from a Canadian base access to the knowledge and expertise available at Canadian universities. The grant supports short term R&D projects to solve a problem specific to the company. The company and the researcher must not have worked together before.

University or college researchers can apply to launch a new research collaboration with an industrial partner through a short-term research and development (R&D) project that applies their expertise to address a company challenge. Partnering companies gain by having the expertise of the academics focused on their R&D issues and by discovering what the researchers and the students working with them have to offer.

Engage Grants support well-defined research projects undertaken by eligible university and college researchers and their industrial partners. A maximum grant of $25,000 over a period not exceeding six months will be awarded to support the project costs.

An Engage project must be aimed at solving a company-specific problem through the generation of new knowledge or the application of existing knowledge in an innovative manner. It must be focused on specific short-term objectives. All proposals must provide evidence that they will create a strong partnership between the participants as well as detailed planning and sound budget justification. They must also clearly spell out the underlying assumptions, intended approaches, milestones and deliverables. As an Engage Grant aims to develop a research relationship, the project plan must detail regular interactions between the participants.

(2015, www.nserc-crsng.gc.ca/index_eng.asp)

NSERC CRSNG

CANADA EXCELLENCE RESEARCH CHAIRS (CERC)

Launched in 2008, the Canada Excellence Research Chairs (CERC) Program supports Canadian universities in their efforts to build on Canada's growing reputation as a global leader in research and innovation. The program awards world-renowned researchers and their teams up to $10 million over seven years to establish ambitious research programs at Canadian universities. These awards are among the most prestigious and generous available globally.

In May 2010, the first group of Canada Excellence Research Chairs was announced. Selected through a rigorous, multilevel peer review process, these chairholders are helping Canada build a critical mass of expertise in the four priority research areas of the federal government's science and technology strategy:

- environmental sciences and technologies;
- natural resources and energy;
- health and related life sciences and technologies; and
- information and communications technologies.

In June 2011 the Government of Canada announced the creation of 10 new awards. These new Canada Excellence Research Chairs are being awarded in the four priority areas, as well as in other fields of research. A minimum of three Chairs will be awarded in areas related to the digital economy under the information and communications technologies priority area. At least one Chair will be allocated to each of the remaining three priority areas, and four Chairs will be open to all areas of inquiry.

(2015, www.cerc.gc.ca/about-au_sujet/index-eng.aspx)

SOCIAL SCIENCES AND HUMANITIES RESEARCH COUNCIL (SSHRC)

Social Sciences and Humanities Research Council of Canada | Conseil de recherches en sciences humaines du Canada | Canada

The Social Sciences and Humanities Research Council of Canada (SSHRC) is the federal research funding agency that promotes and supports postsecondary-based research and training in the humanities and social sciences. By focusing on developing Talent, generating Insights and forging Connections across campuses and communities, SSHRC strategically supports world-leading initiatives that reflect a commitment to ensuring a better future for Canada and the world.

Created by an act of Canada's Parliament in 1977, SSHRC reports to Parliament through the Minister of Industry.

We support research and talent that are central to quality of life and innovation.

SSHRC-supported research in the social sciences and humanities enhances our understanding of modern social, cultural, technological, environmental, economic and wellness issues. It raises profound questions about who we are as human beings, what we need in order to thrive in complex and challenging times, and where we are headed in the new millennium.

The work SSHRC supports encourages the deepest levels of inquiry. It spurs innovative researchers to learn from one another's disciplines, delve into multiparty collaborations and achieve common goals for the betterment of Canadian society. Research outcomes are shared with communities, businesses and governments, who use this new knowledge to innovate and improve people's lives.

SSHRC also invests directly in Canada's future. Through the social sciences and humanities, students receive the best possible training in critical thinking, complex decision-making and creative exploration. By investing in scholarships, fellowships and research training, SSHRC helps develop Canada's best and brightest scholars and researchers into Canada's future leaders.

RESSOURCES AQUATIQUES QUEBEC (RAQ)

Ressources Aquatiques Québec (RAQ) is a strategic cluster supported by the Fonds de recherche du Québec – Nature et technologies (FRQNT). Its regular members are affiliated with Université du Québec à Rimouski, Université Laval, Université du Québec à Chicoutimi, Université de Sherbrooke, Université de Montréal, Université du Québec à Montréal, the École Polytechnique de Montréal, INRS-IAF, McGill University and the CÉGEP de la Gaspésie et des Îles. Several researchers from various federal and provincial government departments, as well as researchers from other Canadian provinces or other countries, are also affiliated as government researchers or researchers from outside Quebec. Its members carry out aquaculture- and recreational/commercial fishery-related research projects.

In aquaculture, RAQ researchers focus on fish, mollusc, crustacean, and microalgae/macroalgae production and participate in joint projects using their expertise in engineering, genomics, quantitative genetics, health, microbiology, physiology, nutrition, behaviour and ecology.

RAQ has always had very close relations with the Quebec aquaculture sector, including the Société de développement de l'industrie maricole (SODIM), the Société de recherche et de développement en aquaculture continentale (SORDAC), the Centre de transfert et sélection des salmonidés (CTSS) and several private sector and government partners.

For further information, please visit **http://raq.uqar.ca**

Ressources Aquatiques Québec RAQ

ATLANTIC CANADA OPPORTUNITIES AGENCY (ACOA)

Summary of ACOA's role and investments in Atlantic Canada's Aquaculture Industry

Established in 1987, the Atlantic Canada Opportunities Agency (ACOA) is the federal department responsible for the Government of Canada's economic development efforts in the provinces of New Brunswick, Prince Edward Island, Nova Scotia, and Newfoundland and Labrador. With offices throughout Atlantic Canada, ACOA works with business and communities to make Atlantic Canada's economy more innovative, productive and competitive. In addition, ACOA ensures that Atlantic Canada's interests are reflected in both the policies and programs developed by other departments and agencies of the federal government.

ACOA has a broad mandate to increase employment opportunities and earned income in the Atlantic region. The Agency has identified aquaculture as one of several strategic sectors for Atlantic Canada. Through the Atlantic Innovation Fund (AIF) and the Business Development Program (BDP), ACOA has worked in partnership with industry stakeholders to make investments in innovation and infrastructure that build upon the aquaculture industry's competitive advantages. For instance, since the inception of the AIF program in 2002, ACOA has made AIF contributions towards R&D aquaculture projects.

Aquaculture R&D Projects related to Fish

- Genome Atlantic (Pan Atlantic): Atlantic Cod Genomics and Broodstock Development to Enhance the Commercialization of the Cod Aquaculture Industry.
- Genome Atlantic (Pan Atlantic): Assessment of Polyploid Physiology and Production Traits in Atlantic cod.
- Genome Atlantic (Pan Atlantic): Development of Camelina as a Feed Supplement for the Aquaculture Industry.
- Cooke Aquaculture Inc. (NB): Development and Implementation of Aquaculture Stock Traceability.
- Huntsmen Marine Science Centre (NB): Development of an Atlantic Salmon Broodstock Facility to Enhance Commercialization Opportunities.
- Research Productivity Council (NB): Development of a new Fish Pathogen Diagnostic Tool for the Aquaculture Industry.
- Scotian Halibut Limited (NS): Development of Certified Halibut Broodstock to Enhance Commercialization Opportunities.
- University of New Brunswick (NB): Integration of a Multi-Trophic Aquaculture Research and Development to Mitigate the Environmental Impact of Marine Cage Culture.
- University of New Brunswick (NB): Effluent Treatment System for Land-Based Aquaculture to Mitigate Effluent Discharge.
- Université de Moncton (NB): Broodstock Research and Development related to High Pedigreed Arctic Charr to Enhance Commercialization Opportunities.
- Cold Ocean (NL): Integration of Physiological, Biochemical, Genetic Innovation for Atlantic Salmon Aquaculture in Newfoundland and Labrador.
- Memorial University (NL): Support for Atlantic Cod Broodstock Development and Fish Health Management Protocols to Enhance Commercialization Opportunities for the Aquaculture Industry.
- Aqua Bounty Canada Inc. and Aqua Bounty Farms Inc. (PEI): Generation of Technology to Produce Reproductively Sterile Atlantic Salmon.
- Atlantech Engineering & Associates Incorporated (PEI): Advancement of Water Recirculation and Effluent Treatment Technology for the Land-Based Aquaculture Industry.
- Atlantic Veterinary College (UPEI): Healthy Fish, Healthy Environment, Healthy Food.

Young Atlantic Halibut in tank. Photo: Nancy House (DFO)

- Atlantic Veterinary College (PEI): Creation of a Centre for Aquatic Health Sciences to Support the Regions Aquaculture Industry.
- Novartis Animal Health Canada (PEI): Platform Development and DNA Vaccine for Koi Herpes Virus.
- Novartis Animal Health Canada Inc. (PEI): Mitigation of Infectious Salmon Anemia (ISA) by Vaccination and Genetic Selection.
- Solarvest (PEI) Inc.: Microalgae Oils for Salmon Feed Nutraceutical Application.

Aquaculture R&D Projects related to Shellfish and Seaweeds

- PEI Aquaculture Alliance (PEI): Management of Invasive Species (e.g., Tunicates) Fouling Aquaculture Farms.
- Université de Moncton (NB): Technology and Services to Enhance the Commercialization of the Shellfish (e.g., Oysters) Industry.
- Acadian Seaplants Limited (NS): Cultivation of Seaweed Biomass for Human Food and Biomass for Active Compounds for use in various sectors (e.g., Agriculture, Nutrition).

For information please consult **http://www.acoa-apeca.gc.ca**

Atlantic Canada Opportunities Agency

Agence de promotion économique du Canada atlantique

MINISTRY OF AGRICULTURE, FISHERIES AND FOOD (MINISTÈRE DE L'AGRICULTURE, DES PÊCHERIES ET DE L'ALIMENTATION DU QUEBÉC – MAPAQ)

The Ministry of Agriculture, Fisheries and Food (Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec – MAPAQ) promotes the sustainable development and competitiveness of the fisheries and aquaculture sector in Quebec. MAPAQ contributes, with its partners, to the implementation of strategies and programs to promote innovation.

Through Innovamer, its financial support program, MAPAQ supports research and development technology transfer activities, technical assistance services, monitoring services for aquaculture and environmental data as well as initiatives to disseminate information. It encourages collaboration between industry, institutions, and organizations in R&D.

MAPAQ finances the fund dedicated to research and transfer in freshwater aquaculture managed by the inland aquaculture research and development corporation, Société de recherche et de developpement en aquaculture continentale Inc. (SORDAC). MAPAQ also funds organizations active in R&D such as Merinov and the Salmonid Selection and Transfer Centre (Centre de transfert et de selection des salmonides – CTSS), and sits on their administration boards.

Agriculture, Pêcheries et Alimentation
Québec

Past its prime and grounded near Baie du Cap Vert in the Magdalen Islands, this boat remembers days long past.
Photo: Dan McPhee (DFO)

MERINOV

Merinov, the Quebec Innovation Centre in Aquaculture and Fisheries, was established in June 2010 by MAPAQ, the Cégep de la Gaspésie et des Îles, and the University of Quebec at Rimouski (UQAR). The center was established by regrouping well-recognized entities and teams:

- MAPAQ Centre for Mariculture in the Magdalen Islands (Centre maricole des Îles-de-la-Madeleine – CeMIM);
- MAPAQ Marine Aquaculture Centre in Grande-Rivière (Centre aquacole marin de Grande-Rivière – CAMGR);
- MAPAQ Aquatic Products Technology Centre in Gaspé (Centre technologique des produits aquatiques – CTPA);
- Halieutec College, a center for technology transfer from Cégep; and
- Research teams from UQAR.

Merinov provides innovation to the fishing industry and aquaculture throughout the province of Quebec. The Centre conducts applied research, experimental development, and technology transfer to generate new knowledge and technologies useful to the fishing, aquaculture, and aquatic product processing industries.

It provides technical assistance to businesses throughout Quebec and is involved in the monitoring and dissemination of information.

Merinov has four centers in the maritime region equipped with basin rooms, pilot plants, laboratories and versatile equipment. It has boats and measuring equipment for operations at sea and in lagoons. Merinov relies on approximately 90 employees recognized for their multidisciplinary expertise, know-how and high quality work in the development of innovative solutions. They work with several organizations in the fisheries and aquaculture sector as well as Quebec and foreign universities.

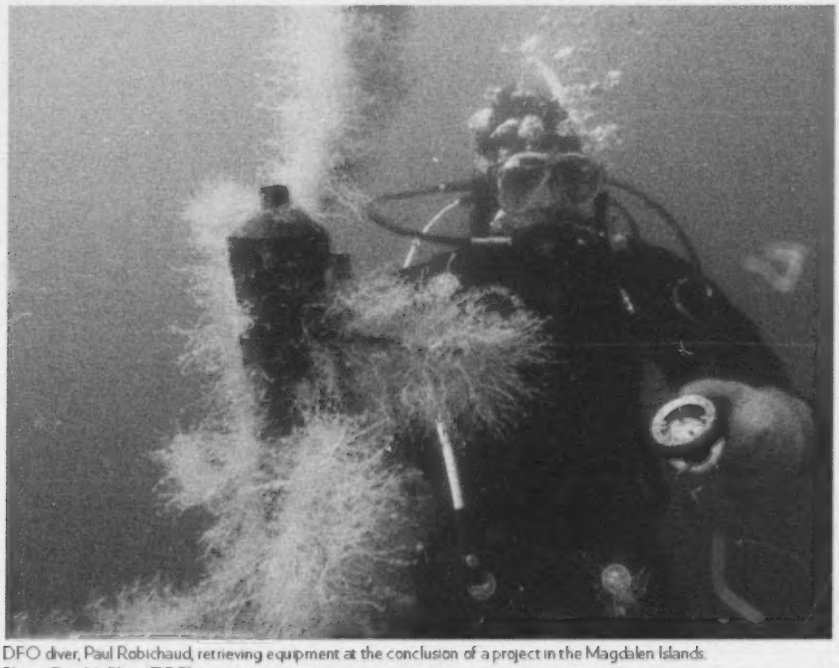
Merinov is a not-for-profit organisation posted at four centres located on the Gaspé Peninsula, the Magdalen Islands, and the North Shore.

Through its services and activities – research and development, technology transfer, technical assistance and monitoring – Merinov contributes to the sustainable development and competitiveness of Québec's aquatic biomass fisheries, aquaculture and valorisation industry.

Merinov carries out projects involving research and development, monitoring, technical assistance and technology transfer to contribute to the sustainable development and competitiveness of Québec's aquaculture industry.

For its aquaculture sector, Merinov counts on a team of nearly 40 employees to successfully accomplish some twenty projects underway on the Gaspé Peninsula, North Shore and the Ma[illegible]alen Islands.

(2015, www.merinov.ca)



DFO diver, Paul Robichaud, retrieving equipment at the conclusion of a project in the Magdalen Islands.
Photo: Dan McPhee (DFO)

GENOME CANADA

Genome Canada is a not-for-profit organization that acts as a catalyst for developing and applying genomics and genomic-based technologies to create economic and social benefits for Canadians. Genome Canada connects ideas and people across public and private sectors to find new uses for genomics, invests in large-scale science and technology to fuel innovation,and translates discoveries into applications, new technologies, societal impacts and solutions across key sectors of national importance, including health, agriculture, forestry, fisheries & aquaculture, energy, mining, and the environment.

To ensure effective management and monitoring of Genome Canada funded projects and science and technology platforms, Genome Centres have been established in each region across Canada. These Centres facilitate access to leading edge technology for researchers, allow for different approaches to project development and fundraising, and provide opportunities for public outreach programs at a regional level.

Vision
To harness the transformative power of genomics to deliver benefits to Canadians.

Mission
- Connecting ideas and people across public and private sectors to find new uses and applications for genomics;
- Investing in large-scale science and technology to fuel innovation; and
- Translating discoveries into applications to maximize impact across all sectors.

GenomeCanada

Objectives

1. Respond to societal needs by generating discoveries and accelerating their translation into applications

2. Attract greater investment in genomics research from a broad range of stakeholders, in particular the private sector

3. Enhance the impact of genomics by transforming knowledge of the ethical, environmental, economic, legal and social challenges and opportunities into sound policies and practices

4. Enhance the recognition of the value of genomics by increasing stakeholder appreciation of genome science, its applications and its implications

(2015, www.genomecanada.ca)

GENOME ATLANTIC

Genome Atlantic is a not-for-profit corporation that aims to help Atlantic Canada benefit from genomics-based research and development. They help develop, procure funding for and manage small-and large-scale genomics projects throughout Atlantic Canada.

Genome Atlantic is focused on areas that can have solid social and/or economic impact, and covers human health, mining, energy, the environment, forestry, agriculture, and aquaculture. Areas of particular interest to the aquaculture sector may include:
- **Disease Management** Genomics research can inform earlier diagnosis, management and prevention of disease;
- **Production Efficiency** Genomics can help producers increase growth or other desirable traits by informing the broodstock selection process; and
- **Feed Enhancement** Genomics can help us identify reactions to different feeds, thereby enhancing our ability to fine-tune feed formulas for optimal fish health.

Genome Atlantic regularly engages with the aquaculture sector and the government and regulatory bodies surrounding the industry to determine the priority areas of research. It also supports specific activities that help to explore and quantify the challenges and respective ROI of proposed research.

In addition to this, Genome Atlantic fosters strategic genomics-based R&D by:
- Linking industry to relevant genomics-based research expertise;
- Facilitating partnerships between companies, researchers and other collaborators;
- Identifying and helping to procure appropriate funding;
- Supporting proposal development initiatives such as workshops, reviews, and budgeting; and
- Guiding and/or implementing R&D project management paradigms, financial oversight, and reporting structures.

Genome Canada is a major source of funding for many of the projects that Genome Atlantic helps to develop. However, Genome Atlantic is not limited to Genome Canada funding mechanisms and actively pursues other sources of funding such as NSERC, ACOA, NRC-IRAP and others that are appropriate to the size and scope of the R&D initiative.

To date, with a wide range of partners, Genome Atlantic has helped to generate over $70 million in genomics-based research in the Atlantic region, and continues to look for ways to build on this foundation with targeted, strategic research.

GenomeAtlantic

GLOSSARY

a.i.	Active ingredient
AAFC	Agriculture and Agri-Food Canada
AANS	Aquaculture Association of Nova Scotia
ABMA	Aquaculture Bay Management Area
ACAIRDN	Atlantic Canada Aquaculture Industry Research and Development Network
ACFFA	Atlantic Canada Fish Farmers Association
ACOA	Atlantic Canada Opportunities Agency
ACOA-AIF	Atlantic Canada Opportunities Agency – Atlantic Innovation Fund
ACOM	Assimilation Capacity of Organic Matter
ACPNB	Association des Conchyliculteurs Professionnels du Nouveau-Brunswick
ACRDP	Aquaculture Collaborative Research and Development Program
AGRG	Applied Genomics Research Group
AIF	Atlantic Innovation Fund (ACOA)
AIS	Aquatic Invasive Species
APC	Artificial Positive Control
ArA	Arachidonic Acid
ARDI	Agri-Food Research and Development Initiative
AVC	Atlantic Veterinary College (UPEI)
BC	British Columbia
BCPOL	BC Pacific Oyster Ltd.
BCSFA	BC Salmon Farmers Association
BCSGA	BC Shellfish Grower's Association
BCWD	Bacterial Cold Water Disease
BIO	Bedford Institute of Oceanography (DFO)
BKD	Bacterial Kidney Disease
BMA	Bay Management Area
BOD	Biochemical Oxygen Demand
CAAHRD	Centre for Aquatic Animal Health Research and Diagnostics
CAAPBL	Charlottetown Aquatic Animal Pathogen and Biocontainment Lab (now GBU-AAHL)
CAER	Centre for Aquaculture and Environmental Research
CAHS	BC Centre for Aquatic Health Sciences
CAIA	Canadian Aquaculture Industry Alliance
CARTI	Centre for Applied Research, Technology, and Innovation
cAS	Cultured Atlantic Salmon
CASD	Centre for Aquaculture and Seafood Development
CAT	Center for Aquaculture Technologies
CATC	Center for Aquaculture Technologies Canada
CCFAM	Canadian Council of Fisheries and Aquaculture Ministers
CCFI	Canadian Centre for Fisheries Innovation
CCFRN	Canadian Capture Fisheries Research Network (NSERC)
CCI	College and Community Innovation Program (NSERC)
CCNB	Collège communautaire du Nouveau-Brunswick
CDBQ	Centre de développement Bioalimentaire du Québec
cDNA	Complementary DNA (Deoxyribonucleic Acid)
CED	Canada Economic Development for Quebec Regions
CÉGEP	General and Vocational College
CERC	Canada Excellence Research Chair
CFI	Canada Foundation for Innovation
CFIA	Canadian Food Inspection Agency
CIMTAN	Canadian Integrated Multitrophic Aquaculture Network
CNA	College of the North Atlantic
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
CPE	Cryptopathic Effects
CRI	Canadian Rivers Institute
CSAS	Canadian Science Advisory Secretariat
CSIRO	Commonwealth Scientific and Industrial Research Organisation (Australia)
CSR	Centre for Shellfish Research (VIU)
CTD	Conductivity, Temperature, and Depth
CTSS	Centre de Transfert et de Sélection des Salmonidés
CZRI	Coastal Zones Research Institute
DAAF	Department of Agriculture, Aquaculture, and Fisheries (New Brunswick)
Dalhousie U	Dalhousie University
DEB	Dynamic Energy Budget
DFA	Department of Fisheries and Aquaculture of Newfoundland and Labrador
DFARD	Department of Fisheries, Aquaculture and Rural Development (PEI)
DFO	Fisheries and Oceans Canada
DHA	Docosahexaenoic acid
DNA	Deoxyribonucleic acid
DNC	Dinitrocarbanilide
DON	Deoxynivalenol
EC	Environment Canada
ECIS	Electric cell-substrate impedence sensing
EDC	Economic Development Canada
ELA	Experimental Lakes Area
EPA	Eicosapentaenoic Acid
EPAQ	École des Pêches de l'Aquaculture et du Québec
FAO	Food and Agriculture Organization of the United Nations
FAP	Fond d'Amorçage de Partenariat
FAWCR	Finfish Aquaculture Waste Control Regulation
FCR	Feed Conversion Ratio
FFAW	Fish, Food and Allied Workers Union
FIMTA	Freshwater Integrated Multi-Trophic Aquaculture
FM	Fishmeal
FONCER	Programme de Formation Orientée vers la Nouveauté, la Collaboration et l'Expérience en Recherche du CRSNG
FVCOM	Finite Volume Coastal Ocean Model
GAA	Gulf Aquaculture Association
GBU-AAHL	Gulf Biocontainment Unit – Aquatic Animal Health Laboratory
GH	Growth Hormone
GHR	Growth Hormone Receptor
GIS	Geographical Information Systems
GRDI	Genomics Research and Development Initiative
HAA	Health of Animals Act
HAMP	Harmful Algae Monitoring Program
HEPA	High-efficiency Particulate Arrestance
HMSC	Huntsman Marine Science Centre
HQP	Highly Qualified Personal
HSMI	Heart and Skeletal Muscle Inflamation
HSP	Heat Shock Protein
HUFA	Highly Unsaturated Fatty Acid
IAF	INRS-Institut Armand-Frappier Research Centre
iBoF	Inner Bay of Fundy
ICR	Institute for Coastal Research
IFAT	Indirect Fluorescent Antibody Technique
IFREMER	French Research Institute for Exploration of the Sea
IGF	Insulin-like Growth Factor
IHNV	Infectious Haematopoietic Necrosis Virus
IMAP	Integrated Management Aquaculture Plans
IMTA	Integrated Multi-Trophic Aquaculture
IOS	Institute of Ocean Sciences (DFO)
IPMP	Integrated Pest Management Practices
IPN	Infectious Pancreatic Necrosis
IPNV	Infectious Pancreatic Necrosis Virus
IPSFAD	Interprovincial Partnership for Sustainable Freshwater Aquaculture Development
IRAP	Industrial Research Assistance Program (NRC)
ISA	Infectious Salmon Anemia
ISAV	Infectious Salmon Anemia Virus
ISMER	Institut des Sciences de la Mer de Rimouski
ISO	International Organization for Standards
ITC	Introductions and Transfers Committee
KCS	Kelly Cove Salmon Ltd.
Lakehead U	Lakehead University
LED	Light Emitting Diode
LPS	Lipopolysaccharide

Lys	Lysine
MAMROT	Ministère des Affaires Municipales, des Régions et de l'Occupation du Territoire
MAPAQ	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MDEIE	Ministère du Développement économique, de l'Innovation et de l'Exportation, Québec
Met	Methionine
MFE	Ministère des Finances et l'Économie
MHA-Ca	Hydroxymethionine Analogue
MSX	Multinucleate Sphere X
MUN	Memorial University of Newfoundland
N	Nitrogen
NAAHLS	National Aquatic Animal Health Laboratory System
NAAHP	National Aquatic Animal Health Program
NAIA	Newfoundland Aquaculture Industry Association
NASAPI	National Aquaculture Strategic Action Plan Initiative
NB	New Brunswick
NBCC	New Brunswick Community College
NBDAAF	New Brunswick Department of Agriculture, Aquaculture and Fisheries
NBRPC	New Brunswick Research Productivity Council
NGO	Non-Governmental Organization
NGS	Next Generation Sequencing Technologies
NHSF	Northern Harvest Sea Farms Inc.
NIC	North Island College
NIS	Non-Indiginous Species
NL	Newfoundland and Labrador
NOAA	Northern Ontario Aquaculture Association
NOAA	US National Oceanographic and Atmospheric Administration
NRA	Neutral Red Retention Assay
NRC	National Research Council
NS	Nova Scotia
NSDFA	Nova Scotia Department of Fisheries and Aquaculture
NSERC	Natural Sciences and Engineering Research Council
NSERC-USRA	NSERC Undergraduate Student Research Awards Program
NSERD	Nova Scotia Economic and Rural Development
NTG	Non-Transgenic
OA	Ocean Acidification
OIE	World Organization for Animal Health
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs (now Ontario Ministry of Agriculture and Food)
OMNR	Ontario Ministry of Natural Resources
OMoE	Ontario Ministry of the Environment
OPC	Opportunistic Polychaete Complex
OSC	Ocean Science Centre (MUN)
OTN	Ocean Tracking Network
P	Phosphorus
PAGE	Polyacrylamide Gel Electrophoresis
PARR	Program for Aquaculture Regulatory Research
PBS	Pacific Biological Station (DFO)
PCR	Polymerase Chain Reaction
PEI	Prince Edward Island
PEI-DFARD	PEI Fisheries, Aquaculture and Rural Development
PEIAA	Prince Edward Island Aquaculture Alliance
PIT	Passive Inductive Transpondor
PP	Plant Protein
PRV	Piscine Reovirus
PSIIRI	Programme de Soutien aux Initiatives Internationales de Recherche et d'Innovation
PSP	Paralytic Shellfish Poisoning
PST	Paralytic Shellfish Toxin
PVC	Polyvinyl Chloride
qPCR	Quantitative Polymerase Chain Reaction
Queen's U	Queen's University
RAQ	Ressources Aquatiques Québec
RAS	Recirculating Aquaculture System
RDC	Research & Development Corporation (NL)
RE	Retention Efficiency
RNA	Ribonucleic Acid
RNAi	RNA interference
ROV	Remotely Opperated Vehicle
RPC	Research and Productivity Council (NB)
rRNA	Ribosomal RNA (Ribonucleic Acid)
RSIV	Red Sea Bream Iridoviral Disease
RT-qPCR	Reverse Transcriptase quantitative Polymerase Chain Reaction
SABM	Société des Amis du Biodôme de Montréal
SABS	St. Andrews Biological Station
SDI	Sexton Depletion Index
SÉPAQ	Société des Établissements de Plein Air du Québec
SFU	Simon Fraser University
SIMCorp	Sweeney International Marine Corp.
SINTEF	Stiftelsen for Industriell og Teknisk Forskning (English: The Foundation for Scientific and Industrial Research) (Norway)
SNP	Single Nucleotide Polymorphism
SODIM	Société de Développement de l'Industrie Maricole Inc.
SOP	Standard Opperating Procedure
SOP	Ships of Opportunity Program
SORDAC	Société de Recherche et de Développement en Aquaculture Continentale Inc.
SPDV	Salmon Pancreas Disease Virus
SSHRC	Social Sciences and Humanities Research Council of Canada
StFX	St. Francis Xavier University
SVCV	Spring Viraemia of Carp Virus
TG	Transgenic
Trent U	Trent University
U Adelaide	University of Adelaide
U Bergen	University of Bergen
U Guelph	University of Guelph
U Idaho	University of Idaho
U Laval	University of Laval
U Manitoba	University of Manitoba
U Moncton	University of Moncton
U of T	University of Toronto
U Paris	University of Paris
U Washington	University of Washington
U Waterloo	University of Waterloo
U Windsor	University of Windsor
UBC	University of British Columbia
UBO	University of Western Brittany Brest
UdeM	University of Montréal
UMCM	University of Moncton Moncton Campus
UMCS	University of Moncton Shippagan Campus
UNB	University of New Brunswick
UNBF	University of New Brunswick – Fredericton
UNBSJ	University of New Brunswick – Saint John
UofT	University of Toronto
UPEI	University of Prince Edward Island
UPEI-AVC	University of Prince Edward Island – Atlantic Veterinary College
UQAC	University of Quebec – Chicoutimi
UQAM	University of Quebec – Montreal
UQAR	University of Quebec – Rimouski
USA	United States of America
USFWS	United States Fish and Wildlife Services
USRA	Undergraduate Student Research Awards
UVic	University of Victoria
VHS	Viral Hemorrhagic Septicemia
VHSV	Viral Hemorrhagic Septicemia Virus
VIU	Vancouver Island University
Wilfred Laurier U	Wilfred Laurier University
WD	Wasting Disease
Western U	University of Western Ontario
WSD	White Spot Disease
WSSV	White Spot Symptom Virus

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(Page 26 – Sea Lice) Female Sea Louse *Lepeophtheirus salmonis* (Photo: Emily Nelson (DFO))

(Page 38 – Fish Health) (Photo: Nellie Gagné (DFO))

(Page 54 – Environmental Interactions) Oysters on the seafloor in an eelgrass bed (Photo: Luc Comeau (DFO))

(Page 69 – CIMTAN) (Photo: Thierry Chopin (UNBSJ))

(Page 80 – Shellfish: Mussels) Traditional static displays of aquaculture (shellfish) as shown at Comox Valley Visitor Centre. (Photo: Stephen Cross (NIC))

(Page 88 – Shellfish: Oysters) Pacific Oyster at a salmon farm in the Broughton Archipelago, British Columbia. (Photo: Allison Byrne(UVic))

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(Page 121 – Organizations) Shellfish lantern nets (Photo: Shawn Robinson (DFO))

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